THE MACHINING OF NON-METALLIC MATERIALS.

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Introduction.

WHILE the moulding art caters for a reduction in costs of production by producing mouldings which need the minimum amount of finishing, there are certain instances where a moulding or piece cannot be produced complete, in which cases machining after the moulding operation has, of necessity, to be resorted to. A brief survey of machining problems and practice met with, which will cover the following compounds used in the moulding industry, will be dealt with to-night. These insulating materials can be classified in order as follows :

(1) Rubber, moulded to form and in bar material.
(2) Synthetic resinous compounds, such as Fabrolite, Bakelite, etc.
(3) Resinous laminated fabric material moulded to shapes or in board form.
(4) Hydraulic bonded asbestos compounds.

Rubber Compounds.

Moulding produced from moulds lack finish and where dimensional accuracy is required, either turning, milling, grinding, or polishing operations usually have to be performed. These operations are done on the standard, single purpose machine tools, met with in any modern machine shop. As in the case of metals, many conditions govern the machining of the non-metallic materials, such as the type of machine, its power and speeds available, the steel or abrasive used for removing material, the correct design of the ultimate tool used, the disposition of the material being machined, etc., so that no hard and fast rules can be laid down, as each individual job has to be considered with due regard to conditions appertaining at the moment.

The cutting speed most suitable for vulcanised rubber depends primarily upon the length of cure that has been given, as variation in the hardness or toughness of the piece is found in different batches of work, so that the soundest policy is to base the correct cutting speed after a trial has been made on one or two pieces taken from any known batch. Consideration must also be given to the diameter of the portion which has to be machined, and further whether metal

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inserts, if any, moulded into position, will form part of the actual faces upon which the cutting tool will operate.

Rubber compounds have a very deleterious effect on the cutting edges of tools, and it is significant to note that the high speed steels which are in the main satisfactory when used for cutting metals, fail lamentably from a production point of view, when in service upon the non-metallic materials, as the sulphur contents in the compound create undue heat, and therefore friction, which in turn burns away the cutting edge of the tool very quickly. In the event of high speed steel *having* to be used, then an important point to remember is that the steel must be heat treated so that a dead hardness is obtained, as this can with safety be allowed for, since practically no shock is transmitted to the tool when in use. A recommended Brinell hardness number for high speed steel tools is approximately No. 665, which from experience has proved to give the longest production life possible.

Touching upon speeds in general for any compounds being machined ; this point may be ignored if the best cutting tool is used, such as the Diamond or the special alloy metals now marketed, which have undoubtedly revolutionised the whole machining practice of the non-metallic materials. An exception, however, to the latter statement must be made when dealing with bodies which present broken peripheries or unbalanced shapes, as often the speed has then to be determined by the strength of the machine available.

When grinding a high speed steel turning tool, for use on rubber compounds, it is necessary to use a very fine abrasive and then oil stone the face and edge, as otherwise, if a rough ground surface is left, the friction generated between the job and the tool will very quickly cause a dulled edge.

When turning the periphery of an object at high speed, a good standard rake for the tool is 25°. Practical experience has proved that a high speed tool will lose its cutting edge in less than two minutes actual cutting time ; further, that it is impossible to turn a parallel diameter and to retain the correct colour of the material, and lastly a smooth surface.

It has been stated that tools for machining rubber compounds should be hardened to practically a dead hard almost brittle condition to obtain the longest cutting time, but even while this statement is true up to a point, it often happens that it may be necessary from a production point of view to revert to the opposite conditions. This may seem rather a contradictory statement, but rubber compounds and their machining characteristics often leave the experienced machinist guessing as to what method will prove itself the wisest and most efficient to the particular job in hand.

Out of the many cases in mind I will just quote one in particular. A job having six operations, turn top diameter, face, radius, bore chamfer and screw, was set up and tried out using high speed steel

tools hardened, but after the job had been running a certain period, it was noted that the operator spent more time taking out his tools and re-grinding and re-setting same than he spent actually machining the work. Consequently the production was kept at a minimum quantity. After experiments had been carried out using all types of carbon steels these hardened tools were cut out with the exception of the screwing tool. A tool bar constructed to carry two tools was substituted for the five previous ones, located in the square tool box, situated on the saddle. The chasing or screwing tool was arranged at the front of the tool bar, while a *soft* high speed steel tool, which superseded the previous five hardened tools was arranged at a pre-determined position at the back of the tool bar. This multi-purpose tool was shaped to cater for the five operations, and was perfectly flat with no surface rake. In operation the first care was to reduce friction to a minimum; otherwise during the boring operation the work would have splayed, thus causing a badly bell-mouthed result. This possible condition was overcome in the following manner. The operator was given a smooth Swiss cut file and an emery stick, and on every fourth piece that was machined, the soft tool was re-trimmed in position by means of the file and afterwards smoothed or burnished off with the emery stick, so that the temporary cutting edge was replaced. With the previous method of machining using five hardened tools, the average output from each operator was 95 per day of ten hours, or approximately six minutes each piece, but with the new method of using a soft tool, and occasionally reconditioning the edge of same, the average output was increased per operator to 450 per day of ten hours, or roughly 1¼ minutes each. Thus, by a simple unconventional method, the production of this particular job was actually increased by 400 per cent. which, of course, was an achievement, and in many cases since, it has been found more economical to use a soft tool and trim the cutting edge in position on the lathe than actually by the use of hardened tools, which had to be broken down and reset each time they needed re-grinding.

High Speed Tools—Rubber Compounds.

When rubber compounds are turned with high speed tools, at a peripheral speed of about 1,000 feet per minute a large amount of trouble is met with, in keeping a good colour. This speed of 1,000 feet per minute is often used for roughing purposes or for the preceding operation of grinding, when colour is of no importance, but for short duration jobs this speed is most suitable.

By experimenting with different speeds with high speed steel it has been found that the slower the speed the longer the tool lasts, giving the job a better finish and colour. Another point with a slow speed is that the rake on the tool must be taken off. When working with a slow speed and with a tool ground with the usual top rake

of about 25°, it will be noticed that the tool has a tendency to enter the job or bury itself into the compound with a lead equivalent to the top rake. If this is not remedied the only result will be scrap. To save scrap and to machine the compound successfully with a slow speed, a negative rake of about 5° *must* be used.

Now, when using tools such as circular form tools, recessing tools, or flat radius tools with a slow speed, a change in the general instructions is necessary, because these tools, often made in the tool room at a greater expense, need a lot of nursing in order that a good result and a clean finish may be obtained. It is necessary with the circular tool, for instance, to recess the faces and only allow about one mm. land at the back of the form to stop any undue binding caused by compound shrinking on to the back of the tool. When feeding these tools on to the job the best results are obtained by a quick and even feed to the stop, taking the tool away as soon as possible after feeling the stop. While an even pressure is applied on the tool a clean cut ribbon waste will leave the job, but as soon as the pressure is arrested by the stop, a fine dust takes the place of the ribbon waste, which will lap away the edge of the tool, if it is allowed to rub on the face of the job. This applies to all single purpose tools which have to finish with one operation.

When using a radius tool for any particular form, it is very necessary that the tool is made with a true full radius or form, to ensure the safety of the job. Often a very large radius or form is cut on the face of a job with a single purpose tool by the method mentioned, and providing the strain of the tool on the job is even back and front, and the job strong enough in body to stand it, a 2½-inch radius form can be cut without a chattered finish.

Speeds.

The present day demand of manufacturers is high production based on one thing—speed. In the production of pieces from rubber compound there are two terms of speed to be used, periphery speed and feed speed. These two speeds are main factors in the production of metallic objects, but put to a different use, in the production of non-metallic objects. In the case of a costly form tool, peripheral speed has to be lowered, but this can be brought even from a production standpoint by an increase in feed speed. Here you see three points in general production problems brought out, that is, " weak resistance " enabling a high " feed speed " and a " slow speed " to preserve the tool. If these tools are used with a high peripheral speed, the result is always a spongy finished surface, with no guarantee of size consistency, and often the necessity of having to grind as much as $\frac{1}{16}$-inch to $\frac{1}{8}$-inch of the tool away, to remove the damaged edge. This also proves that the higher the cutting speed, then the more probable is the body of the material being machined liable to spread itself into the cutting edge of the tool, thus very

quickly lapping this away for a considerable depth, which as explained is sometimes as much as $\frac{1}{8}$-inch.

When machining a body with a broken surface, a further consideration is necessary. If a slow speed and a high feed is used the result will be either the body smashed or the off edge of the body sufficiently chipped and broken to scrap the job. For the safety of the job, and a successful machining result, the edge of the tool has to be sacrificed, by the use of high speed and slow feed. In this case it is often necessary for the operator to hand feed the tool, very sensitively, to counteract the pushing action of the tool when the edge has been dulled by using the high speed.

Special Steel Alloys and Cutting.

When this type of job is in production and a fairly large number are required, it is often necessary to tool the job according to the number of operations, and the estimated length of time it will take to complete it. If, for instance, a machine is set up to produce a job in large quantities, it is very necessary to discard the high speed tools and use the more expensive tools, namely, the Diamond or Widia metal. Taking for example the first named, the Diamond, this tool has never failed with its cutting properties at high speed when machining rubber compound, but owing to its other limitations, the Diamond is only used on really special jobs. When a Diamond is made up into a tool the price paid for it always determines the size, and on the other hand the size of the Diamond always determines the actual production. It is always the practice in workshops, when Diamonds are used, to relieve them of heavy duty and make a roughing operation first, and then use the Diamond for finishing. The price of a Diamond with a cutting edge about $\frac{1}{8}$-inch L. is in the vicinity of £5, and of the cutting edge only about $\frac{1}{16}$-inch can be used with safety. If the Diamond is overloaded in operation with a cut too large, the rubber compound will gradually eat away the setting, finally making another expense, that of re-setting the Diamond. The cutting properties of a Diamond when used as a turning tool are unparalleled, being able to cut at excessive speeds, with a feed to suit the size. These Diamond tools will cut rubber compound for an indefinite period, and providing no trouble is experienced by foreign bodies, will last until the setting is lapped away by the waste material.

Synthetic Resin Compounds.

When machining synthetic resin compounds high speed steel has to be definitely superseded by either the Diamond or the special cemented tungsten carbide metals, such as Widia, etc., as these latter metals, if we may so term them, will retain their cutting edges against the abrasive actions of the synthetic resinous compounds.

When the diamond tool is used greater care is needed than when

machining the rubber compounds, as synthetic resin compounds give a greater resistance, and as the weakness of the Diamond tool is in its setting, if due care is not exercised by the operator, the Diamond can easily be stripped from its mounting.

A peculiarity of this compound is that it will, in due time, crumble the cutting edges, which condition, if allowed to continue will develop a main crack across the body of the Diamond, the resistance of the compound thus forcing it from its mounting.

A typical example of the capabilities of a Diamond turning tool used on a synthetic resinous bonded moulding, where one face approximately 4¼-ins. diameter by ½-in. wide had to be machined perfectly flat, can be shown in the following results.

The moulding was set up in a lathe running at a peripheral speed of 1,300 feet per minute, and the time taken for machining this face was 10 seconds, using a depth of cut of approximately $\frac{1}{32}$-in. This tool, in use ten hours per day for approximately 30 working days, machined some 8,000 pieces before needing re-setting. Thus it will be appreciated that the choice of cemented tungsten tools only gains an advantage from the manufacturer's point of view so far as initial cost of tools is concerned, inasmuch that the cutting qualities of these special metals compare appreciably with the Diamond, with the added advantage of a lower initial cost and further, it must be clearly understood that a diamond cutting tool cannot, under any circumstances, be used for machining purposes, where any metal inserts are embedded on the face being machined. To amplify this statement, the re-setting of a Diamond tool may cost anything from £2 to £3, apart from the possibility of the loss of the value of the Diamond by its splitting when being taken from its original setting. Another factor to be allowed for is the length of time the Diamond tool may be out of commission before being returned for use in the shop.

Summarising, one can say with certainty, that the most efficient and economical tool for machining the synthetic resinous compounds is the one made from the special cemented tungsten carbide metals, as previously mentioned.

The compound under consideration, being mainly composed of a wood meal filler, will tend to burn at the point where the waste turnings are leaving the face of the job, so that due care is needed when setting the tool to give ample clearance in order to minimise the possibility of the waste igniting, as it is common in machine shops where this compound is being machined to actually see the waste smoulder, and sometimes break into open flame, thereby creating danger to both operators and premises.

It is, therefore, a sound policy when laying out a shop for the machining of synthetic resinous compounds to specify concrete floors, and non-inflammable materials in the construction of same.

Grinding.

Grinding plays an all important part in the general machining of all classes of compounds, and should be adopted when possible in preference to cutting, especially where extreme accuracy is required. Any good class grinding machine may be used, providing adequate protection of journals is catered for in their construction, in order to ensure the minimum entry of particles of abrasive waste which, mixing with the lubricants used for cooling purposes, finds its way into every crevice of the machine, thus in time clogging and eating away the bearings. The upkeep of machine tools in general, where cooling lubricants other than oil are used for compounds, is a considerable item in a manufacturing concern engaged on this class of work.

With regard to running speeds for abrasive wheels these are usually determined by the maximum safety speed permissible for the machine being used, an average speed for external grinding being in the region of 2,500 revs. per minute. For internal grinding the speed of the spindle is generally about 13,000 revs. per minute. The recommended grain of the abrasive for external grinding practice is 46-M, 60-M to 60-P, the particular wheel used being determined according to the special operations required to be done. For general grinding on open surfaces, the softer wheel can be used but when sharp corners are needed on the job, such as a spigot and face, then the harder wheel, such as the 60-P is necessary.

For roughing operations where the wheel can be fed directly on to the diameter of the job, then the 46-M (softer grade) wheel will hold its surface for an indefinite period, provided that an adequate flow of lubricant is used. When it is necessary to trim the wheel the usual procedure of truing with a Diamond must be followed up by a final trim lightly using emery cloth soaked in oil, as otherwise a scratched effect will be reproduced on the surface of the job. This finishing or smoothing operation of the periphery is not a recognised operation for ordinary grinding of metals, but for grinding compounds it is very necessary to give the wheel a little extra gloss, and at the same time remove any loose grains which stand proud of the periphery for, minute as these grains are, they may cause a lot of trouble if not removed.

When mounting a job on the grinding machine between centres, great care has to be taken when setting the poppit or tail stock, so as to avoid too great a tension on the spring of the back centre as, if this tension is neglected, it will be very difficult for the operator to guarantee a consistency of size and finish, or even a semblance of concentricity. Take, for instance, a piece of rubber compound, mounted on centres ready for a grinding operation, if a strong tension is used on the back centre, then a second action is set up, that of the centre grinding away the pivot centre in the job, causing a change in the running concentricity, which will be magnified

considerably when the wheel is doing heavy duty on the one side. In fact, on rubber compounds it has been known that the back centre, when used with a strong tension, has actually embedded itself in the pivot of the job through constant seizing up, finally acting as a wedge and splitting the piece in two parts, which may cause grave danger to the operator, and of course scrap the job. When due care has been taken in the correct setting of the machine, it is quite possible for the proper grade wheel to run for a week without needing re-trimming.

These grinding operations on all compounds are the most successful and economical from a production viewpoint, where accuracy is very necessary. There is always a great compensation when grinding rubber, that the periphery of the wheel can be used with great success for multi-purpose results: for instance, a particular job which, in the ordinary way merited two operations, these being " grind parallel diameter, radius and face " and " grind taper to length," meant two distinct settings on the grinding machine. The job was run under ordinary conditions with two settings, but a drawback about this job was the fact that the first location had to be used for both operations and settings, making it impossible to guarantee concentricity of the two diameters. A change was made in the selection of the wheel, the final choice being a 60-M one inch wide, this superseding a wheel 46-M $\frac{5}{8}$-inch wide. The machine was set for a parallel result, the wheel being trimmed correctly to a female gauge from the male gauge of the job. When this was done, the faces of the wheel were given adequate clearance to eliminate any possibility of clogging when bedding on the full form. In this particular case the wheel had a very heavy duty to perform, grinding $3\frac{1}{2}$ mm. off diameter and $2\frac{1}{2}$ mm. off the back face. When in operation, the wheel was fed on to the job, and the resultant total time was found to be the same as for the previous first operation. It will, therefore, be seen that this meant the completion of the grinding in one operation, with a guarantee of concentricity, with also an increase of production from 800 to 2,000 per week. When grinding the harder compounds, such as the synthetic resinous compounds, to obtain the same results it is often necessary to use a harder wheel, such as the number 60-P. With the use of these closer grained and harder wheels, it is necessary to make the grinding allowance of a minimum figure, as this compound has a tendency to burn and clog the wheel. This minimum grinding allowance must be decided by the size of the actual job, taking into consideration whether it is a solid body, or a hollow one, with the possibility of warping or springing taking place.

Internal Grinding—Rubber.

When resorting to internal grinding on rubber compound, exceptional results can be obtained by this method, when accuracy with

fine limits is needed. Generally on small diameter jobs the flow of cooling lubricant is substituted by a wind blast through the head of the machine, which draws the waste out through the hollow spindle. The speed of the spindles run between 13,000 to 15,000 revs. per minute according to their construction, but so far as the correct speed suitable for the compound is concerned, the higher the better. As is often the case with rubber mouldings, an ample allowance is left for the machining operation, sometimes between two mm. and three mm. which can be ground away on a single journey of the wheel, the return journey clearing and bringing the bore parallel.

Considerable expense is saved by making these internal wheels from old ones which have been used for external grinding, and it is interesting to note that better results can be obtained than with specially made internal wheels. This type of internal grinding wheel will do heavy duty consistently, only requiring a trim with a Diamond once a day. When larger diameter jobs are being ground, it is often necessary to revert to the water flow, also to use a little grease on the wheel. The high running speed of the wheel, together with the thick atmosphere of dust created in the bore, often causes a waterproof shroud, at the cutting edge of the wheel, thereby inducing undue heat at this point, which will change the stability of the compound, and be the means of giving a variable result on the work. The reason for adding a small amount of grease on the wheel is apparent as directly heat is generated the grease flows, thus preventing the wheel from clogging.

An even better method is to employ the wind blast as previously mentioned, this being a more economical proposition.

When grinding resinous compounds a variation in methods and "feeds" is necessary as the density of this compound is greater than that of the rubber compounds due to the relative higher hydraulic moulding pressures used, and a harder and more brittle surface is created for machining purposes.

It is therefore impracticable to satisfactorily *cut* a broken surface, and here again a grinding operation has often proved to be the only successful and economical method to produce a sound job. One particular job, a moulded piece having a bore approximately two inches diameter, with a moulded keyway some $\frac{3}{8}$-ins. wide by $\frac{3}{16}$-ins. deep, had to be machine finished in the bore, to a very close limit. The estimated time for completing this operation allowed for turning, but on trying out this method it was found impossible to prevent the tool from chipping the unsupported offside edge of the keyway. Apart from this consideration, the finish of the bore was not considered good enough as, although the feed of the tool was fine, a corrugated effect was obtained, whilst is was very necessary that the finish of the bore was of a smooth, glossy appearance.

The turning operation was replaced by an internal grinding

operation using a wheel grade 60-P and the chipping of the keyway edge was entirely obviated, and although in this case the grinding operation took a somewhat longer period, the results more than justified the additional labour cost as the scrap factor was reduced to practically nil.

Lapping.

The operation of lapping is closely connected with internal grinding, inasmuch as many jobs are moulded practically to the finished size, but due to slight variations met with the final size is obtained in these cases by the method of lapping.

Various types of lapping bars are employed, according to the class of work in hand, and they may be made of steel for use in conjunction with emery cloth, or brass when using emery powder and oil.

Lapping is only resorted to when the bore of the work is to be finished to a close limit, without the bore being absolutely concentric with the outside diameter, as this operation is decidedly quicker to perform than setting up the work on an internal grinding machine. Assuming that a moulding having a parallel bore moulded to within .005-ins. of the required finished dimension has to finish at say.001-ins. tolerance, then in this case a steel lap, mounted in the spindle of a lathe and on to which the moulding would be placed, will quickly and consistently lap the bore to gauge size. The actual lap consists of a steel bar turned at the front end with a slight taper lead, the parallel diameter of same being a running fit in the moulded bore, in order to act as a pilot for the portion of the lap which is to reproduce the gauge size required. This lap portion is then reduced in a diameter by a total of two thicknesses of emery cloth, and a saw slot sufficiently wide to take one thickness of emery cloth is cut through this, followed by a further diameter which is made a running fit in the finished lapped bore. The emery cloth is cut into strips the same width as the slot and threaded nearly through. The remaining length, which is determined by the circumference of the lap, is then folded over. In operation the job is pushed on to the pilot bar and the operator, with a rotating movement, works the job in a longitudinal direction forward, one movement usually being sufficient to size the bore. A skilful operator can with this method handle on an average some 200 to 250 pieces an hour up to a two inches diameter bore. Sizes above two inches diameter cannot with safety be lapped, as, due to the larger surface area the human element cannot hold the work against the lap, so that for sizes of two inches diameter and upwards the internal grinding machine has to be used.

The brass lap is used in cases where the bore is practically to finished size, within say .001-ins. to .002-ins. of the required limit, and also where a good smooth finish is essential. As in the case of the steel lap, only diameters up to two inches can be successfully finished by this method. Brass laps are made of good quality hard brass, and

assuming that this type of lap were to be used in lapping a bore similar to that previously described, the design and construction of same would be generally as follows :—

A tapered portion is turned at the front leading end, followed by the finishing diameter, which is lightly serrated in order to carry the paste compound made of emery powder mixed with oil. The operation of lapping is again the same as for the steel lap, the great advantage of this method being that a parallel bore is ensured, as under certain moulding conditions, where tapers on members are required for extraction purposes, a parallel bore cannot be obtained on the moulding. A further advantage is that the finished lapped bore can be machined to tolerances as close as plus or minus .0005-ins.

General Milling Practice for Non-Metallic Materials.

Careful consideration has to be made in deciding the clamping or jigging method adopted for holding non-metallic materials when milling operations need to be performed, as often stress, created by the pressure required to hold a piece rigid under the action of the cutter, is very near the breaking point of the compound from which the moulding is made. It is, therefore, a more practical policy, wherever possible, to substitute the operation of milling for one of grinding, this latter operation being done on the same basis as that of the milling operation. Actual practice has proved that more economical results can be obtained by " miller-grinding " if it can be so termed, than by milling, where milling cutters can be replaced by abrasive wheels. Cooling lubricants are not as a general rule used on these " grinding-miller " operations, but it is essential that the dust waste is removed by suitable extraction plant in order to safeguard the health of the operator.

One of the most successful operations performed on the milling machine is that of straddle grinding where two sides of a piece can be ground parallel at one operation. In certain instances where a flat face has to be machined, and metal inserts are embedded in the compound, thus presenting two distinct machining conditions, then the milling cutters will often prove more satisfactory than the abrasive wheel, because with the use of the latter more heat is generated on the surface being machined which often tends to loosen the insert. On the other hand care must be taken to ensure that a light cut is taken so that no shock is imparted by the cutter when striking the insert, as this will either rip the metal inserts out of the compound or cause the piece to break, due to excessive strain set up by clamping. Even when using the milling cutter, it is not advisable to choose standard cutters having a coarse tooth pitch, as the best results are obtained by cutters having a fine tooth pitch. Therefore suitable cutters have to be made especially for the job, and even these have a tendency to chip away the off-edge at the end of the cutting stroke.

Summarising, preference should always be shown for the abrasive wheel rather than the milling cutter, where conditions permit.

Drilling Practice.

Where it is possible to eliminate drilling in compounds, by moulding the holes direct during the moulding operation, then this policy should be followed in all cases.

In certain cases of mould design, where moulded holes are allowed for by the use of mould pins, the subsequent high cost of replacing broken mould pins, due to the relatively high pressures used in moulding practice, often is the means of determining that a drilling operation should be allowed for after the moulding operation has been completed. This drilling may be of a simple nature, and carried out without the use of a special drill jig, in which cases the position of the holes is usually spotted in the mould. This practice specially applies to the synthetic resinous compounds, as holes can be kept within closer limits of accuracy between given centres than in the case of the rubber compounds. This latter compound, which has a greater shrinkage factor than any of the other compounds, cannot be relied upon to keep to given dimensions, and it is therefore very necessary in many cases to provide drilling jigs for locating purposes where accuracy is required on the finished job.

Asbestos compounds do not give good results when drilled, as the mouth of the hole tends to break and chip considerably. Even moulded holes do not consistently show extremely good finished results as the poor flowing qualities of this compound often cause bad homogeneous knitting at one side of the hole. It is true, however, to say that the practice of " spotting holes " from the mould considerably lightens the cost of drilling, simplifying the handling and enabling a relatively larger output per working day to be obtained. Two methods of drilling are therefore met with, these being " spot drilling " and " jig drilling."

As in the case of the machining of the non-metallic compounds, drilling practice causes extreme wear on tools, as special metals, such as the cemented tungsten carbeloys previously mentioned, cannot be made up into drills, so that high speed steel drills only can be used. Although many firms produce drills in different steels, these being mainly of the orthodox design met with for metal drilling, until recent times the problem of special drill design for the drilling of the non-metallic materials was ignored, as it was assumed that if a drill was capable of use on metals, then with a relatively softer material to work upon the same drill should be even more efficient for the compounds. This is a fallacy which has been proved in actual practice, as very special considerations need to be made in essential points of design of the drill before its maximum efficiency can be obtained. Cutting speeds for drilling practice are always determined by the size of the drill while the feed is

regulated by the skill of the operator, where sensitiveness is of paramount importance. A good average speed for drills up to $\frac{1}{4}$-ins. diameter is 4,500 r.p.m. and for drills from $\frac{1}{4}$-ins. to $\frac{1}{2}$-ins. diameter this speed must be reduced according to the increase in diameter to a speed of approximately 1,000 r.p.m. for the $\frac{1}{2}$-ins. diameter drill.

Before using the ordinary twist drills, considerable alteration needs to be made to ensure safety to the job, and also to the operator. Firstly, the shape of the flute must be altered by replacing the positive rake by a negative one, and secondly, the flute must be ground out as much as possible towards the back of the opposite land or cutting edge. These are very necessary modifications, as a larger space will be obtained, thus enabling the waste material to get away easier and minimise clogging, and also reduce to a low degree the atmospherical conditions inside the hole. A third alteration needs to be made at the cutting edge of the drill, the length being determined by the depth of the hole, or whether the hole extends right through the job. In the case of a hole, the depth of which gives a considerable bearing to the diameter of the drill, and going through the job, the cutting edge can be extended and ground to an angle of about 60°. A negative rake, however, must be used, otherwise when the drill breaks through and its pivot is lost, the job will be picked up at the same feed as the pitch of the flutes, and may cause harm to the operator and the job, by badly smashing the back of the hole, where the drill leaves the job. When a shallow through hole is to be drilled, the length of the cutting edge can be shortened to a smaller angle in order to retain the pivot bearing as long as possible but in addition to this a second edge ground at 60° must be made, so that a clean hole at the back edge is obtained.

In many cases where drilling is necessary and the wall of material between the hole and the edge of the moulding is of a very weak section, demanding extra care and the minimum amount of friction, it is very important to reduce the width of the land of the drill for this purpose. Although this practice reduces the life of the drill to a minimum, in the majority of cases it is the only successful method possible.

Feeds for Drilling Practice.

In grinding and backing off standard drills, to obtain the necessary clearance suitable for use on compounds, it is obvious that the drill loses a certain amount of strength and rigidity, although the strength of the drill is still more than sufficient for the work it has ultimately to perform. This question of strength is important when considering the best feeds for the drilling of non-metallic materials, because the success of this operation depends entirely upon sensitiveness and quick action of the operator. In fact the smartness of the operator when feeding the drill will often double

the life of the drill between the time of grinding and the reconditioning of same.

When drilling the rubber compounds it is extremely important that the drill is *not* allowed to dwell whilst running, for if it is not fed into the work with a steady, quick even movement, the cutting edges will immediately be polished away. This condition will in turn create friction and heat, with the result that no cutting action will take place. The best results are therefore obtained by the operator feeding in the drill at the coarse feed until the compound commences to get hot, when it will be noticed that a puff of smoky fume will escape from the mouth of the hole. When this condition is obtained the operator *must* immediately withdraw the drill from the hole in order to clear it of waste compound, which, due to heat, has re-moulded itself to the full shape of the drill flutes. This practice that is, quick feeding and withdrawing, should be continued until the point of the drill is on the verge of breaking through, when the drill can then be finally withdrawn to clear the waste and with a steady and sensitive feed re-fed into the hole and the drill allowed to break through. The results obtained, by careful attention to the methods advocated above, should ensure a clean cut hole with the minimum amount of chipping at the back edges.

The methods outlined apply to all compounds where the waste will re-mould itself to the shape of the drill flutes when cutting, due to the heat generated by the friction of the drill and the compound.

When drilling asbestos compounds, the speed of the drill must be reduced to about 800 r.p.m., combined with a coarse feed. The extreme abrasive action of this compound has been known to burn and in turn soften the drill. In one particular example noted by the author, a drill in use actually twisted after getting hot, so that when examined afterwards it was found that the flutes were in the opposite direction to their original position. The cause of this was simply through the operator not feeding in the drill sufficiently fast enough as it must be appreciated that when a slow feed is used the compound will grind away the cutting edge of the drill and will continue to grind until the heat generated causes the drill point to become red hot, after which the binding action created will finally cause the drill to collapse. It will be seen that the important points to be taken care of are to reduce friction, and further, to clear the waste from both the drill and the hole frequently by a quick even feed and withdrawal.

In instances where larger size heavy duty tools, such as spot face cutters, or special plate cutters are to be used, then the opposite condition to drilling practice must be observed. This is done by a light feed with a corresponding slow speed, so that the waste is lightly cut and not broken, as in the case of drilling, keeping the ratio between feed and speed as near constant as for drilling practice.

Tapping Threads.

When threads are required they may be either moulded in or tapped, according to which method is the most suitable and economical. In the case of machined threads, either special tapping machines, such as the Garvin, or tapping heads mounted in the ordinary drilling machine spindle may be used. The most suitable speed of the spindle for successful tapping is around 800 r.p.m., and the sizes of the taps generally met with in practice are from 6 BA to $\frac{3}{8}$-ins. diameter Whitworth. The plug tap is always tapered up to about three to four threads when tapping straight through holes, but in the case of blind holes, the tap is only relieved on the first thread. A very important point to be taken care of on the plug tap when dealing with blind holes is to see that the flat face at the leading end is relieved by grinding the flutes to practically a conical form, so that the waste cannot be trapped between this face and the bottom of the hole, as otherwise if the flutes were not relieved, the waste collecting at the bottom of the hole would cause an upward pressure as the tap fed in, and thus cause the threads to strip. In practice the core diameter is made approximately 10 per cent. larger than the theoretical core diameter, so that a 90 per cent. thread only is obtained.

It should be noted that tapping machines and tapping heads must be used with the utmost care, combined with sensitiveness on the part of the operator, as in certain cases holes are tapped in as short a time as two seconds, so that if the trip of the machine or head is not timed very accurately, then the thread will be stripped without any warning. Special care has also to be shown in the choice of the operator and in most cases it is necessary to train the operator specially for the operation alone.

Polishing and Sandblast Operations.

Polishing is only resorted to where the moulded piece leaves the mould without a very good finish, and also depends to a great extent upon the compound from which the moulding or piece is made. For instance, the synthetic resinous compounds, such as fabrolite, bakelite, etc., when moulded give an exceedingly high finish, providing the mould surfaces are in turn highly polished. However, after moulds, and especially hand moulds, have been in commission for a lengthy period, it often happens that slight scratch marks appear on the moulding surfaces, and if it is essential for a high finish to be obtained, then in these cases polishing has to be resorted to after moulding.

Rubber compounds have to be polished, as, no matter how highly polished the mould may be, pieces made in this material will not reproduce a correspondingly high finish from the moulding operation, and therefore polishing becomes essential. Where, however, machining operations have been previously carried out

on these compounds, polishing is not always a sound proposition as no matter how careful the polisher may be, unfortunately machined edges, which need to be kept sharp, are buffed off so that they become radii, and so do not conform to specification. Sand-blasting is, therefore, the better method of the two, and will be dealt with more fully later.

Referring to polishing generally, this can be divided into five distinct operations, namely,

(1) Disc Grinding.
(2) Dry Bobbing, using 120 emery powder.
(3) Grease Bobbing, using flour emery.
(4) Mopping using linen mops with brushing emery paste or lustre.
(5) Swansdown Mop, for cleaning and final polishing.

The operations above are classified in order of finishing, the disc grinding being the roughest method available, the dry bobbing, the next, and so on until swansdowning is the final finishing or glossing operation.

Disc grinding nearly always precedes the polishing operation proper, and may be used for removing large or rough projections such as flash joints on mouldings, or again for creating a flat locating surface needed for a subsequent machining operation, in which case it becomes, in effect, a cheap substitute for the usual operation of " miller grinding " previously referred to. Although disc grinding when preceding a polishing operation may appear more or less a roughing operation, care has to be shown on the part of the operator by handling the job lightly and sensitively, or otherwise the compound surfaces will be badly burned, thus spoiling the colour, which condition may ultimately scrap out the work on inspection. The spindle speed for disc grinding may vary from about 1,000 r.p.m. downwards, according to the compound being treated.

Dry bobbing is done where disc grinding is unsuitable, and in the preparation of the bobs the following practice is adopted. The bob comprising hard felt, is turned on its spindle by means of suitable hand tools and trimmed by a piece of carborundum abrasive, after which the periphery is coated with glue, and whilst in this condition, the bob is rolled in emery powder then dried for a period of 48 hours. It should be noted that the quality of glue used is of the very best to ensure the correct working conditions of the bob. The spindle speed in this case is approximately 2,500 r.p.m. and surfaces can be very efficiently and quickly scurfed.

After the operation of dry bobbing comes grease bobbing, where a similar felt bob is impregnated with flour emery in like manner to the dry bob. Grease, usually " Albo " or Russian tallow, is applied to the periphery, and the operation smooths out the scratch marks made by the preceding operation of dry bobbing and prepares the

work for the mopping operation, the spindle speed approximating the second operation.

Next in order comes the mopping operation which, as mentioned, comprises a loose linen fabric which again is impregnated whilst running, with "brushing emery paste" or lustre, combined with a proportion of grease. After this operation has been performed. it is noticeable that the surface and colour of the work begins to become smooth and pleasing and the final swansdown mop gives the required high finish, this being used perfectly dry and running at about 2,500 r.p.m. Synthetic resinous compounds do not have operation 1 and 2 performed on them, unless exception is made to disc grinding for location surfaces, whilst rubber compounds usually have all operations from 1 to 5. Asbestos compounds and also the bituminous or pitch compounds are not treated to any of the operations mentioned, and in like manner the textolite compounds are very rarely treated.

Sandblasting.

Mention has been made that this operation is more satisfactory than that of polishing, as sharp edges can be maintained. The finish obtained by sandblasting is of a pleasing grained appearance, but is distinctly different from the finish made by the polishing sequence of operations.

After sandblasting the pieces are cleaned with oil, in order to take away the dull surface, and also to remove the minute particles of sand which adhere to the surfaces.

To ensure successful application of this method it is essential that operation No. 3, referred to under polishing, that is, flour emery bob used without grease, is carried out prior to the actual sandblasting. This is necessary, in order to remove indulations on the surfaces, as the sand only grains the surfaces to which it is applied and does not cut or remove indentations or foreign markings.

The plant used for sandblasting is too well known in the metallic industries to warrant a detailed description in this paper, it being sufficient to say that slight modifications of construction only are made when used for the non-metallic industry, the fundamental principles remaining the same. In conclusion, the author desires to express his appreciation and thanks to Messrs. British Thomson-Houston Co. Ltd. for their kind permission to present this paper, and Mr. H. T. Richardson for his assistance in preparation of this paper and for illustrations.

Discussion, London Section.

MR. MCGUIRE: I think we must congratulate our lecturer on the remarkable way in which he has delivered his paper. It is quite evident that he is most practical with every subject he has brought forward. Although he has not touched a wide range of non-metallic substances he has touched sufficient to create considerable interest this evening. I should like to ask him why it is necessary to grind some of the mouldings he has mentioned this evening when, so we are told, we can get mouldings from the mould within limits of plus and minus 2. Perhaps that has something to do with the insulating properties of the materials. Also I notice he does not use cooling compounds. (I myself, do not use them)—but is that because they affect the dialectrics of the materials under operation? Our lecturer has spoken about cutting up many parts with a grinding wheel, but as regards fibre and bakelite sheets, I can obtain a much better finish with a metal saw. I have experimented with many different kinds of wheels (grain and grade) and, so far, have failed to produce an edge equal to that produced from the saw in spite of the assistance I have received from a grinding wheel manufacturer. It is also much more economical with a saw. I was interested in the drill that was passed round to us. Mr. Phillips mentioned that he used a special drill for the majority of the operations, but did he notice that the drill was not one of these? We also use a special drill, which is made at Sheffield, called a bakelite drill, but with a much slower and wider spiral than the English manufacturers adopt. This allows a much easier exit of chips and no undue heating of the drill. I quite agree with him in his shaping of his cutting edge, but even with that it fails to remove the burs on the other side of the work, and in a good many instances creates extra work in getting rid of those burs. I am well aware of the fact that all tools must be kept sharp, but we still have burs. Also taps. I notice he mentions a special grinding he puts at the end of the taps, to facilitate threading, but I think that if you increase the angle of your spiral rather sharply at the end of the tap, you will get similar results with much less trouble, also in difficult threading operations I very often reduce the lands of the tap thereby increasing the width of the flutes, clip clearance is very important for good threads. Polishing: In polishing ebonite and vulcanite, we sometimes get two distinct kinds of finish on the same stick or piece of material, also you will find one part of the rod or sheet quite solid and another part spongy. Could our lecturer explain the reason for this? On one occasion through failing to polish a group of ebonite parts, which were made to certain specification, we returned them to the moulders, who treated them and sent them back polished equal to those which had already been polished. These parts were machined before sending, and

were returned without alteration to dimensions. Can our lecturer explain the treatment these received ? May I go off that and go on to some subject with which I deal in particular ? You have not mentioned press tool work this evening. That plays a very big part in the manufacture of non-metallic substances. There are some kinds of ebonite we can blank and some we cannot. To what thicknesses can we use ordinary dies with sheet ebonite, using similar tools as are used in the metal trade, and what type of tools do you suggest above that thickness ? Eronoid is also a non-metallic substance rather off your paper, but I do not know whether you can enlighten us on the matter. In tapping erronoid with a standard tap you probably get a thread that is anything from plus 5 to 10 thou. large. What is the reason of that ? Is it due to the heat ? Bakelite, about which we have spoken this evening, is also used quite frequently and in short runs. What would you say would be the thickest material we could push through an ordinary type die as used in metal work, and what type of die would you use above that thickness ? Further, as we spoke a lot about edges this evening, do you think a keen edge or slightly dulled on a die would produce best results ? As we have not mentioned fibre I will leave that, but in the course of Mr. Phillips' remarks I can thoroughly endorse his experiences with the cutting of non-metallic substances—that is, you must not dwell at any period with a cutting edge on non-metallic substance. Should you stop in the midst of a cut, upon the restarting of the feed, you will find the materal giving way to the pressure of the cut and sometimes collapsing, besides taking the edge off the tool . The best rake I have found is about 30°. We use Widea tipped tools on the majority of operations. High speed steel is only used where Widea is not applicable. I have experienced similar trouble to our lecturer in the case of having many tool stations on one machine, due to one or more tools not standing up to its work. May I suggest that you split the operations upon two machines instead of one. Although you have doubled your machine hour rate, the actual cost per piece is cheaper.

Mr. Phillips, replying to Mr. McGuire : I think the first question was " Why do we grind different compounds, and does it reduce the dielectric strength of the compound ? " In the case of the resinous bonded compounds it does reduce the dielectric strength. Immediately the resin bond is broken the dialectric strength is reduced considerably, but in the case of rubber it does not touch it. A piece of rubber 1 fal thick will stand, according to my figures, 300 to 500 volts per fal thick so that it does not interfere with the rubber compounds but with the resin bonded compounds : as soon as the face is broken down then it does interfere with the dialectric strength. The guaranteed limits of grinding mouldings are not consistent. Where the limit is consistent you may get your depth

quite O.K., you may get your diameter O.K. in one place, but you cannot guarantee the concentricity of the job because these jobs—all of them—are more or less alive. You may gauge this compound correct to gauge, but if you put it in storage you will find that it has grown. Taking the different temperatures from the moulding machining, and the different temperatures that have generated during machining, you can imagine how many times it grows and shrinks : it will grow and shrink every time there is heat generated into it. The grinding is more or less to guaranteed diameter and, of course, flatness. That is one of the main factors, and with these jobs that are alive, you cannot guarantee from moulding a definite flatness, but the grinding is brought in to guarantee in special limits.

You mention saw slots. I perfectly agree with you ; I have a sample. This has been straddle-ground and it has been followed through with a saw straight through a brass insert on each leg. With the metal tool no matter what speed you are running at you cannot guarantee the edge of that tool to keep up. If you run it at a slow speed you get your back edge, or the end where the tool runs off, chipped. You are bound to get that unless you are thoroughly supported right to the full diameter of the cutter so that you are dead on to the bottom of the slot : you will get a chip. But I agree with you in some cases, especially in the smaller thicknesses or the smaller widths of the slot, then you have to use a saw, but for the larger widths if you get an abrasive to stand up to it, it is far in front of the ordinary saw. I agree with you also in the burring of drilling. We do have trouble. It does not matter what tool you use, you will get a bur, and in fact in the majority of cases the burling tool you put in will throw a bur. I have got over that by using the special cemented tungsten carbide with just a single tooth cutter sweated on to the side of a pilot—that is providing the hole is big enough to stand the pilot, but if it is not big enough you have to use the ordinary bur-removing tool. Tap lands : I agree with you also with tap lands, but I do not agree with you about grinding the back of the land away until the tooth is very thin. I always believe in grinding the front or the cutting edge of the tap instead of the back ; on the other hand, you have to keep the width of that tooth for the actual life of the tap. Keep grinding at the front ; it is new life to the tap every time you grind—otherwise it would be a very costly operation. The special twisted drill that I handed round, you will notice that it is not one of the special drills that we use actually on the job. That drill was given to the operator purposely for a sample of what this asbestos compound will do. It is not the ordinary asbestos but it is a compound. The ordinary asbestos that you can pick to bits is a different thing altogether—but with that compound, if the drill is not cleared away at the back it will *cause what is going round on that drill.* With a

forceful feed you will cut it up as right as rain, but with a slow feed then you encourage heat which will gradually bring the point of the drill red hot, and then you will see the drill collapse altogether. You get differences in the polishing of ebonite stick and you will get different glossy effects. These sticks are cured in bars, in tubes, and sometimes the fellow who looks after the vulcanizing process may have part of the bar near the door, and so part of the compound will not be so hot as the other parts. You get a variation there. In one spot you may get the bar a little bit spongy ; in another place you will get it hard. Again you may get a variation if you have the grain twisted, and if this is so, you will get a difference in colour. You mentioned about a better polish from the makers of the compound. You must bear in mind the fact that the people who make this compound know the name of the compound. Anything that is put on the market as a compound is as good as a trade secret. I have a bar of rubber compound here ; I do not know who made it, but it is a certain fact that in this (you can almost bite it) there is something that will cut and scratch glass. It is a trade secret and is covered by the word " compound." The people who make the compound should know how to polish it, but none the more for that, you can get different colours and you can get a better polish on compound by reducing your speed ; another thing, you can get a better polish on compound by using bull-hide *on the* mops and leave the felt alone. There are some things that you can do a lot with press tools, but, candidly speaking, I would not recommend piercing for the ordinary Bakelite or Fabrelite. I would not recommend that. Then you ask whether I propose a dull edge to the die or a keen edge. I should certainly advocate a keen edge because, sooner or later, it would become dull ; with the plunge of the material it is bound to come, but if you have a dull die, or a die with a radius on the front—that is to say with a certain amount of the diameter of what is going to be plunged through—it is going to be in the air if it is brittle. Unless it is supported in every way you will get nothing but collapse.

You mentioned tapping eronoid. You take the making of a tap ; hardening taps are not ground, only along the flute—they are hardened. You will agree with me that there is no guarantee of that tap being dead flat. Another thing, I know I can say that with nine makes out of every ten if you make them up before you put them into the job you will find that they are between 5 and 10 thou. oversize for the machine tap—between 5 and 10 thou. oversize, good English-made taps that are going to oust foreign products. You also mentioned about my five tools. You evidently misread my paper because in the paper I particularly stated that the five tools were cut out and replaced by one soft tool . That one soft tool was made and ground to suit the five diameters, and then the screwing tool, the chasing tool, was put at the pre-determined

position front of that tool so that when the tool was in action at the near side of the job the chaser was right out of action, clear of the job at the back ; then when the tool had finished the chaser was brought in and the thread was cut. Cooling lubricants used with grinding or with turning. I do use these, but it has no effect whatever on resistance. Paraffin induces cutting to high-speed steel tools. To fetch dialectric strength up another operation, that of recuring, has to be performed.

MR. J. CAMPBELL ROBB : I believe you said in your paper that some of your cuttings caught alight. If you had been using a cutting compound would that not have prevented ignition ?

MR. PHILLIPS: Yes, it would have prevented it, but for ordinary metallic machining the machines are not adapted. When this compound ignites it is a very bad practice to throw water. The strange part about it is that the minute you throw water on it it bursts into flame, but if you keep sand there is none.

MR. MCGUIRE : I should like to state here that you get much better results (especially on short runs) on sheet bakelite by taking the keen edge from the smooth punching tool. A slightly dulled die will give you a better punched edge than one that has a very sharp edge. The ordinary punch and dies we keep very keen and can pierce and punch material up to $\frac{3}{32}$-ins. thick.

MR. FERGUSON : I should like to ask Mr. Phillips if it is possible to dovetail a tooth in one of the gear wheels as I have been in the unfortunate position of having to dovetail a tooth in on occasions when I have been right away from the factory.

MR. PHILLIPS : The dovetailing must be terribly large. If you cut a piece out big enough you have to undermine four or five more teeth. Then you may get the required result or it may smash your wheel up.

MR. WEBSTER : Is it true to say that it is impossible to use any coolant on laminated mouldings ? (MR. PHILLIPS : No, you can use coolants on them). I mentioned that because we had a particular job of drilling to do across the section and ordinary coolant was used on the job ; subsequently they were unfortunately scrap. The laminations had actually spread. With regard to the taps. I do not know whether you have ever tried a single-fluted tap. A single-fluted tap, with about the first ten threads tapered right the way down, you will find is very effective. You taper the tap until it will enter the drill hole. Immediately the one cutting edge which is left will proceed to cut and gradually open the hole out to the diameter of the tap, and it cannot cut bigger than the tap. You mentioned that taps are not ground except in flute. That is hardly true. Ground taps are on the market in all shapes and forms, and you will find that the flanks of the thread in itself is ground true with the centre and also the shank, so that should overcome your trouble with burring due to the tap not being true.

MR. PHILLIPS : While that may be true with die taps or taps used in the metallic industry, the majority of the ordinary common or garden machine taps are not ground ; they are merely polished or lapped up. They look as if they have been ground, but I think they are ground along the flutes to clear the hardening compound off the edge. In the case of the laminated compounds, if the laminations had parted through the use of the compound, I am afraid it was not a very good moulding. I have laminated mouldings that will stand a compressive strength perpendicular to the laminations of 40,000 lb. per square inch ; compressive strength parallel to the laminations, they will stand 25,000 lb. per square inch. I would like to pass a remark on the single-flute tap. I agree with it in one way, but in the other way I do not agree with it because with the single-flute tap, or the master tap, in the non-metallic industry it has a rolling effect which in due time is bound to shrink the hole small again after it has been rolled out once. It won't cut right the way through ; it is bound to roll or stretch, then it will give rather lively effects. I have used plenty of spiral flute or two-flute spiral taps and got good effects from them, but I have never used single-flutes.

MR. MILLER : You will find that the tap will be greedy. It makes a larger hole. The trouble with taps is that when you are making dies you make tackle taps and you do not use them until they have gone through ; and then with grinding you get burs, and if you clean the taps out with cast iron and then use them on erronoid, you will find you get results that you want. But the course of the thread will always crumble ; there is no strength in it.

MR. E. J. H. JONES : I suppose that most of us here this evening are working on harder metals than have been spoken about and we think we have the world's worst job of work, but after listening to Mr. Phillips we perhaps have a different idea, and we may be nervous of the speeds and feeds he is able to run at, and we may still think we have the world's worst job of work, but we can congratulate the author on the care he has taken in preparing the paper, the thoroughness with which he has been through every detail of the machining operations, and with the way also in which he has answered the questions. I am sure you wish to join with me in a vote of thanks to him this evening. Mr. Phillips, we thank you.

MR. PHILLIPS, replying to the vote of thanks, said : I thank you all very much for the cordial reception that I have had. I have enjoyed myself since I have been in London, and I do not think I shall forget it—but, candidly, although I have been in the non-metallic industry now for nearly fifteen years, this is the first lecture I have ever given, but these lectures are running day by day in the workshop.

Discussion, Birmingham Section.

Mr. R. H. YOUNGASH, Section President, who presided: I am quite sure we have listened interestedly to what Mr. Phillips has told us, and it is very interesting to me to realise that other people besides ourselves have troubles. Mr. Phillips' paper has very largely dealt with how to avoid as well as how to do things. Sometimes we are inclined to think that we individually have all the troubles and get hump-shouldered carrying the weight of the universe, but evidently other people do have troubles. I do not think that you will be able to, in any way, contest anything that Mr. Phillips has said to-night. I am rather inclined to think that all you will want to do is to ask him questions.

MR. J. A. HANNAY: I think Mr. Phillips has given us a wonderful start, and I feel very proud that the Institution has been able to have such information available to put in its Proceedings. The Chairman spoke of what must be in most of our minds; after listening, we must want some further information. Some of my questions may not seem very reasonable, but may bring out a little further information. Mr. Phillips spoke about cutting these rubber substances, keeping a steady feed, and not letting it run out. There is a clear feeling that you do not get very accurate dimensions. I should like him to give us some idea as to limits. He mentioned various coolants for rubber, etc. Do you not generally, in cutting rubber in the ordinary way, use plenty of water and a fairly clean knife, and do you use water in the same way when you are machining these rubber compounds? I think Mr. Phillips must have made a mistake in referring to costs of certain diamonds. I raise that question so that he may correct himself or tell us why they cost so much. Another point I would like him to give us some information on is the definite peripheral speed. He speaks of a quarter-inch drill running at so many thousand revs and a half-inch drill running at so many thousand revs, or an abrasive wheel running at two thousand revs. Can he give us any idea of the diameter of that wheel? It might be large or small but the peripheral speed must be something like constant. The next point was polishing the abrasive wheel. Well, of all the things I have met it seemed to me the most stupid thing to do. I do know some thing of machining, and have always preached that if you want a really nice job, you must dress your wheel up with a diamond. I am going to suggest to Mr. Phillips that he has got to get some better means of dressing his tools. He seems to sharpen them and then go in and dull them. Instead of cutting it is more or less burnishing. I should like to know to what sort of limits he works in pieces, such as are displayed here. My impression is that we do not get such very fine limits. Where, in metal we should talk of cutting to perhaps a quarter-thou., in pieces like that it does not seem to me they can be kept within anywhere near such limits. Mr. Phillips spoke of the

internal grinding wheels being made from the old wheels. Gentlemen, for about thirty years I have preached that same thing ; only last year I was proved to be wrong, and I found abrasive wheel makers can now make small internal grinding wheels as good as any wheel you can cut out of a big one, and save a lot of money.

MR. H. SPINKS : Mr. Hannay mentioned rubber substances. I should have thought that particular type of material would have tended to fill up the grain of the grinding wheel, and I should like Mr. Phillips to tell us why it does not. When Mr. Phillips was talking about machining some compounds he said he had difficulty in machining those particular compounds with high speed steel and then said the high speed tools were replaced by one tool which did the whole operation with the exception of the threading tool ! If he had experienced difficulty with the rest of the tools, why was it that the grinding tool stood up ? Later Mr. Phillips was talking about drilling tools and said that it was not possible to obtain drills made of the tungsten carbide materials. I have actually seen tungsten carbide tipped drills from $\frac{5}{16}$-ins. upwards. Have you had any experience of using these ? Mr. Phillips spoke of making small internal grinding wheels from stub ends of large ones. Why does he not use diamond tools that he used for making those wheels, for drilling those particular compounds ? With regard to two remarks made by Mr. Hannay, I do not agree. First, if you have a wheel not giving you quite the finish on the job, dress it up with a diamond, perhaps giving you a rougher finish. If you rub the wheel with a carborundum stone it will give you a beautiful finish. For the past three years we have been making our internal grinding wheels ourselves, trepanned out and drilled with diamond tools, and we consider we halve our grinding wheel costs by cutting just the wheel we want from old ones we have had in the works. Mr. Hannay says the makers save you a lot of money by giving you the wheel you want brand new. I do not agree with him.

MR. DARBY : I should like Mr. Phillips to give us some information as to the feeds on drilling and turning, etc. I can see that if you have a heavy feed you get a correct finish. If you have a light finish, I can see the rubber compound will give way and the tool just rip away, which would be detrimental to the tool cutting edge, and then digging into it every third or fourth cut. Can you give me any idea as to what feed you would use consistent with the cutting tool edge and finish of the job ?

Mr. I. H. WRIGHT : Mr. Phillips, in talking about cutting materials, carbon steel and high speed steel, did not mention stellite. Some few years ago, before the days of Widia, I had some experience with turning magneto commutator rings with brass inserts. It was quite a new line to me, and we started out with high speed steel tools which we very soon discarded in favour of carbon steel tools. They were not good enough, and we went over to stellite which was the best

thing then available, and which lasted, as far as I can remember, about five times as long as carbon steel. The work was very light indeed, and the brass inserts involved a fairly strong material. We did not think of diamonds, or could not afford to, and in our experience of this work we formed the conclusion that the best thing to do was to run the work as fast as possible and then to feed as quickly as possible, the feed being dependent on the security of clamping the work and the capacity for standing cuts without being distorted. Mr. Phillips spoke of two extreme cases, one in which you can have a slow rotating speed with a big feed and the other in which you can have a high rotating speed with fine feed. It seems to me that where the work will stand it, a fast feed carries less rubbing as the work is done in fewer revolutions of the work. I should like Mr. Phillips to state a little more definitely if there is any real reason for insisting on fine feed when you have a high speed, instead of having the highest speed that the material and tool will stand and then also the highest feed that the job will stand ? I should like Mr. Phillips' opinion on another point. Suppose he has some very light metallic pieces, copper let us say, and in order to support these he bedded them in a lump of plaster of paris—they were so delicate that they would not stand any kind of machining operation—and then machined the plaster of paris and the copper pieces all at the same time. I should like Mr. Phillips' opinion as to the best cutting material for this plaster of paris and copper, and any comments he would care to make on a case of that kind. I was very glad to hear Mr. Phillips refer favourably to my old friend the slight 60° angle on the lip corner of twist drills. It appears to have been a great thing for Mr. Phillips, but it is not realised generally how good that is in ordinary practice. The ordinary twist drill, working on steel, goes first of all on the very corner of the lips, where on account of the steel angle of the spiral and heavy outside relief, there is a delicate corner, and a 60° angle on the two corners. On any ordinary work, I have found this to be a very good thing, and am only sorry it is not more often used.

I think this paper will be a big attraction in the Proceedings of this Institution, and, in my opinion, is much to be preferred to some of the highly economical papers.

Mr. Gregory : I noticed that Mr. Phillips was stressing all the time distortion of the material, and I wondered whether it was a local distortion immediately on the tip of the cutting tool ? I was very surprised to hear of " M " and " P " wheels being used as abrasive wheels, and also the fact referred to by Mr. Hannay that it was necessary to dress the wheel afterwards. One would have thought that such a material as rubber would have bonded the wheel and given that finish it requires without any additional outside assistance. Mr. Phillips also mentioned the fact that he could go for one day on one wheel truing. I think most of us who handle this sort of thing occasionally find we cannot get one minute without one wheel

truing. I think it is a remarkable achievement and worth coming to this lecture for. Undoubtedly the greasing of grinding wheels of the internal type through little rolled slots seems to be a distinct advantage and it brings me back somewhat to the old textile trade where we used to grind spindles, and the lubricant commonly used on a grinding stone then was a lump of fat. We used to get an excellent finish ! I would like to know whether " one day—one grind " is really the right thing, say if it is being practiced on wheels such as " P " or so forth, and if so, whether they can be fine ground. Therefore, instead of this lapping operation in which he transfers his form to a flexible member like a bob, would it not be possible for simpler shapes if the wheel were moulded to the form, to have the work ground instead of dry-bobbed ? Mr. Phillips also mentioned that he could hold a job on a sandblast for ten minutes without losing a corner. My experience is in hardened steel, and you can lose your shape very rapidly on a sandblast plant in ten minutes.

Mr. Grew : Our lecturer advocated in some instances a high speed but does not appear to have mentioned any particular speed. In my estimation it would have an abrasive effect and it would seem to be more deleterious to the material and the tool than a low speed.

I was rather interested in the three combination tools which he illustrated by a slide, and while one or two of them at least were orthodox more or less, the drilling and tapping was certainly unorthodox, and I should like to ask him whether he has in his experience found it more economical ? It would appear to me that the drilling should be done much more rapidly than the tapping. It would be rather difficult to sharpen the tap and make a really good job of it without injuring the dull at the same time.

Mr. W. G. Groocock : We have to-night enjoyed a very good lecture, but I feel sure that Mr. Phillips will understand me when I say that he has only just touched the fringe of the particular subject with which he has been dealing. I have no intention of criticising anything that Mr. Phillips has said, but there are one or two points where he has been a little ambiguous, and briefly I would like to touch on these. He has told us something of the use of soft tools for this material. That, to me, does not express anything at all, because I should want to know just how soft were the tools in that particular case. He also mentioned the use of tungsten steel tools. Here again I think he ought to have given us some idea of the tungsten contents of these tools to which he was referring. There was another point too, which evidently left a number of people a little bit doubtful, and that is the point he made when he was referring to the inconsistency of the rubber mouldings. This material (rubber) as is generally known, is hardened by rolling sulphur into it, and then curing same by some form of heat treatment. It would help considerably if he could give us some light as to why various jobs are so inconsistent as to hardness. There should be some reason.

Another point which I should like him to correct is one that arose when he was talking of grinding wheels. He mentioned the use of a 60-P wheel. To me that carries no information at all, because the P wheel made by one maker is softer than K, whilst in another case the P wheel is a harder wheel than K. For the information to be complete he should have added the maker's name so that we could then have real information on the subject. Another word he used which was somewhat confusing was " mil." Many people regard this as being .001 of an inch, whereas undoubtedly Mr. Phillips was thinking of a millimetre.

The question of making grinding wheels oneself is, I believe, one that most of us have at some time or other given thought to, and probably believe that we could make them cheaper than we could buy them. About the cheapness of such wheels I have grave doubts, but there is no doubt that quite often a wheel made from the broken centre of another wheel does give good results ; better results than we have had from the use of a wheel made by the wheel makers. The probability is that the good result is due to two facts ; the first that we may be getting a different grit and grade from that which we have purchased from the makers, and secondly, quite often wheels made from broken pieces are more open in the bonding than those made by the makers. This probably makes for better work. I was rather surprised to hear from Mr. Phillips that he had not been able to get some maker to make drills suitable for the work he was talking about. This is surprising considering the numbers that he must have to use. Personally I think the question of getting a maker of twist drills on to the job rather than making drills himself ought to be investigated further. With regard to the point raised as to sand blasting for a matt finish, there is no doubt if the air pressure used is kept low, then matt finish can be obtained without detriment to the corners of the work, even when such work is held under the jet for quite a long time.

Mr. Groocock then proposed a vote of thanks to Mr. Phillips.

Mr. Phillips : The accuracy obtainable when using say form tools cutting on rubber compounds and working to the stop, depends, of course, on the feel of the operator ; that is, if the operator consistently feels the stop with a constant pressure each time, then providing that the cutting edge of the tool is maintained he does not get noticeable variation in his sizes. He is cute enough also to know when it is necessary to re-grind the tool by noting the colour of the work and the finish on the machined faces, but generally speaking the consistency of size is left absolutely to the operators themselves. A further point is to take advantage of the limits given, as a sound policy when machining rubber is to work to the low limit as this compound has a tendency to grow.

The best lubricant is just water. On the internal grinding wheel shown, you noticed that small grease grooves were made in order to overcome the tendency set up, of creating a waterproof shroud at the

cutting point of the wheel. It is a fact that when using a strong force of water on the job, it will not get to the cutting point of the wheel, and the grooves are therefore put into the wheel and filled with grease, so that as soon as heat generates, the grease runs and prevents the clogging or waterproofing referred to. This waterproof shroud, it is curious to note is always brought about practically at the end of the stroke, so that the slight flash of grease or fat which takes place is enough to prevent clogging ; otherwise undue heat would, of course, burn into the compound and give a bad finished effect.

I have always been told that when one of our diamonds go west, " that is another two or three pounds gone west," and I must confess I am trading on that information. I want you to understand that some of the diamonds used by us do not exceed $\frac{1}{8}$-in. on the cutting edg and are rather on the smaller size if anything. One trouble in using diamonds for cutting purposes is that the waste material reaches and eats away the setting, and often when a diamond is taken out of its setting a body crack is found. Taking everything into consideration, such as loss of time, possibly of the diamond collapsing, etc., then I do not think I am far wrong in my statement re price of re-setting this class of cutting tool.

A quarter-inch drill is generally run somewhere about 4,500 r.p.m., and as I have already explained, when we come on to drills up to and over the half-inch diameter, then I strongly advocate leaving these alone, for the reason that my experience has always shown that a drill over half-inch diameter used on the non-metallic materials is dangerous, especially running at approximately 1,000 r.p.m. The force of the machine against the body strength of these materials is more than an operator expects at times, even when holding a heavy job ; sometimes the job will be smashed, with possible danger to the operator, or else a badly chattered finish is obtained.

The grinding wheels I mentioned, that is, external wheels, are usually about 10-ins. diameter, and the spindle speed of my machines is usually about 2,500 r.p.m. My policy on choosing a speed is to take note of the test speeds given to the wheel by suppliers, this usually being about 3,600 r.p.m. and then run at about 2,500 r.p.m. If I could, with safety, run at the higher speed, then I should do so, but safety first to the operators must be kept in mind.

It is, of course, possible to trim the bobs to the form of the job and so considerably lighten the polishing operation. However, there are so many varied shapes and pieces moulded, especially in the distributors shown, that I am afraid we should find it impracticable to trim our bobs. Regarding the question of trimming grinding wheels, our experience has undoubtedly proved that the closing of the grain after trimming, thus giving the wheel a more or less burnishing action, has undoubtedly been the means of obtaining the best results. Limits on rubber mouldings, especially the distributor mouldings,

are fairly close, the tolerance on the spigot after machining being about .001-ins. to .0015-ins., but a curious point about these rubber and synthetic resinous compounds, is, that the experienced machinist sums up their characteristics in the word "alive." Mouldings tend to "age" and in the case of the rubber mouldings tend to grow in size, whilst in the case of the resinous compounds the reverse often takes place. Thus, unless a thorough artificial ageing has been given, by curing the mouldings for certain periods in hot ovens, then the job after it is machined, will, when put away for say a few months be found to have lost its original limits of accuracy.

Referring again to the trimming of wheels. Someone mentioned that he noticed that I have actually run a wheel for a day without trimming. This may sound an exaggeration, but I can assure you this is quite in order, and in fact, one particular job I have in mind, the wheel has done an operation of finishing two diameters at once, and has run for a fortnight without being re-trimmed.

Mr. Darby mentioned in regard to feeds on drilling, that he got a series of digging in movements. You will certainly get digging in and probably cause the job to go up in the air, unless you do put a safety edge on the drill, for the safety of both the job and operator. Usually a negative rake has to be used unless it is just a small cut, say taking about $\frac{1}{16}$-in., when the leverage of the cut is not stronger than the holding of the job.

Mr. Wright mentioned speeds. When machining pieces with a broken periphery, great care has to be exercised, especially when the tool leaves an edge, otherwise chipping will take place along the edge. A very sensitive feed is therefore absolutely necessary to avoid this condition.

Mr. Gregory mentioned the question of distortion, was it local? No, these distortions are caused through heat being generated. This does not get in a local position, but extends over the whole of the job and will not take effect when actually on the machine or wheel, nor on the first inspection but it gradually grows, this eruption taking place through the heat generated from machining.

I mentioned in my paper that I could hold a job over the sand-blast for ten minutes and not make any difference to the machined face. I did not infer that I should hold it there until the face was damaged, but wanted you to understand that the actual sandblast power as used for non-metallic jobs is comparatively light when compared with that used for metallic work. The former is somewhere in the region of 8 to 10-lbs., whilst metallic pieces are usually sandblasted using a pressure of approximately 40-lbs. The sand-blasting power for the non-metallic materials only gives a pleasing grained effect.

Mr. Grew mentioned combination tools. Yes, those shown to-night are certainly unorthodox, but they have proved very economical, often saving an operation. The one tool combines both

drill and counterbore, whilst the other drills and countersinks, thus saving time and an extra spindle.

Speed of tapping was mentioned. You will notice that I spoke of a speed of about 800 r.p.m. for the tapping machine. That is unorthodox. You will find that ordinary speeds for tapping, somewhere in the vicinity of 150 r.p.m. for metals, but when tapping compounds, we can go up to 800, though for that speed we must provide a really sensitive operator. As I pointed out, if the operator does not watch the work very closely, then the threads can be very easily stripped, as it only requires one revolution too much of the tap, for the operator to find without indication, after the tap has been withdrawn, that it is covered with dust, which happens to be the remnants of the thread.

Mr. Groocock asked a question about the tungsten carbide tool. It is the most economical and only efficient tool I have ever used, with the exclusion, of course, of the diamond, but taking into consideration the fact that these tools can be ground on the spot by provision of the wheel especially provided for re-grinding, and practically the same cutting results can be obtained as with the diamond, and as these latter need to be sent away for re-setting, then I should say that in the main the tungsten carbide tools are the most economical and efficient.

As I mentioned it is possible when due care is taken during curing, to obtain slight variations in each batch of mouldings coming into the shop for machining, which although minute, may cause a slight difference in the machining qualities of the work. This condition, however, cannot be controlled, and therefore discretion needs to be exercised by the qualified machinist.

With regard to the makes of the grinding wheels I have advocated, I find that the best for the purpose of grinding are the " P " wheel and the carborundum wheel, say M supplied by the Norton Company. The definition of " Mils " mentioned by Mr. Groocock is correct and is intended to mean .039-in.

Mr. Spinks mentioned the possibility of the rubber compounds clogging the wheels—rubber will not clog unless it is allowed to get heated.

I know that there are certain drills marketed from $\frac{5}{16}$-ins. dia. upwards and I believe even lower than $\frac{5}{16}$-ins. dia. that are tipped, but I have not been fortunate enough to have used these, as we have found that the ordinary drills, ground to suit as I have described, give excellent results, and therefore we have kept to these as standard.

A gentleman asked my opinion about cutting copper which was embedded in plaster of paris. I am afraid I cannot give definite data on this problem because I should need to know the actual strength of the anchorage before the copper could be twisted out of same under the action of cutting, then, I could determine it.

THE COUNCIL IN SESSION AT HEAD OFFICE, LONDON, 4th JUNE, 1932.

Outer seats, left to right: **H. C. Armitage (Vice-President, Birmingham Section), S. Carlton Smith (President, Luton Section), W. S. Marsden (Institution Staff), R. Hazleton (General Secretary), E. W. Hancock (Chairman of Council), J. A. Hannay (late Chairman of Council), G. H. Hales (President-Elect, London Section), W. F. Dormer (President, London Section), W. G. Groocock (late President, Birmingham Section), Hy. Mantell. (Chairman, Examination Committee).**

Inner seats, left to right: **G. Larsson (Hon. Secy. Luton Section), E. W. Field (Birmingham), C. C. Ferguson (Vice-President, London Section), H. E. Weatherley (Past President, London Section).**

(It is regretted that five other Councillors present could not be included in the photograph).

TECHNICAL EDUCATION FOR PRODUCTION ENGINEERS.

Paper presented to the Institution, Birmingham Section, by W. R. Parsonage, B.Sc., M.I.Mech.E., Principal, Chesterfield Technical College.

BY far the greater number of persons engaged in engineering industries are on the production side and by far the greater number of persons entering Evening Technical Colleges are engaged on the production side, and by far the greater number of students who go through the Engineering Departments of the Universities will be engaged on the production side. Yet, with the exception of a few cases only, Technical Colleges and Universities set out their work on a basis to train what might be called engineering physicists or engineering designers rather than productionists. Although far more persons are necessary for making than for designing an article, attention is devoted to the articles to be made rather than to the methods and means of making them. Evening Technical Colleges are too much inclined to copy University curricula, forgetting and leaving one of their own fields of activity, a very great and wide one. The Universities, however, are beginning to feel that production cannot be neglected and are appointing lecturers in production engineering whose duties are to apply themselves to this side of engineering.

Present day mass production methods call for as much skill, knowledge and ingenuity as in the designing of the articles to be made. In a large engineering works there may be only a few capable designers or men of the engineering physicists type, some may be in the main drawing office, and some elsewhere. The number is small compared with the total number of persons employed.

It is when things come into production or when matters of production are considered that real questions of policy are decided. The number or probable number and types of articles to be made determine the methods to be used, the types of machines and accessories, the amount that can be spent upon them, factory location, layout and personnel. The persons who can plan out production, design production machines, jigs and tools, and see that these are properly used and can appreciate the possibilities of any new productive agent or conditions leading to improved production are the most important and highly remunerated men. Yet we seldom set out to give such men the assistance we might do in

27th January.

Technical Colleges. Rather we attempt to divert their interests to other things. We set out our courses for a few designers and engineering physicists forgetting the important and large number of various and increasing types of productionists.

Obviously the productionist should have some knowledge of all operations, and as much manipulative skill as possible, consistent with reasonable time in training. Here the Technical College can be useful in giving to young men some training on the lines of the old all round apprenticeship and in some respects improving upon it. The old time foreman was a task master, with output as his chief function even in the far off days, rather than a teacher. A youth had to pick up what he learnt of his trade as best he could by imitating workmen, some highly and some not highly skilled. We who served our apprenticeships in the old days all know of a few most highly skilled and intelligent men who were our shop godfathers, and to whom we went for advice, men who were only paid the standard rate of wages but were the backbone of their shops. They were not usually chosen for foremen when such jobs became vacant, although they may have been made into working charge hands of early piece-work groups of youths using the then poor production machines and tools. This, owing to bonus hunting, limited the inclinations and desires of these good men to continue to act as shop guides and philosophers. The then employers made but few attempts properly to use the ability of these men and many emigrated to America and became the key men who made possible the building up of the machine tool and other industries there. In America opportunities were given to these men comparable with their abilities ; their gifts were intelligently used in appropriate places in industry ; conditions were made for them or they were allowed to make the conditions whereby they were of greater use in industry and resulting increases in their emoluments followed.

Such men who are natural mechanics and mechanicians exist to-day, and I suggest an extensive employment of them in our Technical Colleges, where, by skilful teaching, youths could be got to any desired degree of manipulative skill and a correct knowledge of tools and machines and their action, in a small fraction of the time taken by the old apprenticeship system. There is some truth in the statement that the old type of mechanic, with the skill inherent in him rather than in the machine, is not now needed. I suggest that he is still needed in key positions. Just before the War you will remember that concern was caused in America by the reduction of the number of emigrants of this type from Europe, and particularly from Great Britain. There were many articles in the " American Machinist " about it and the question was taken up by big firms in America. These men should be one of our problems, but not so much perhaps as the man of some all round

manipulative ability and a keen knowledge and insight into all engineering trades and machine processes ; the man with the further knowledge to put the skill into the machine and the processes. That type of man should also be one and a more important one of our problems. By way of parenthesis I might mention that my experience during the War forced me definitely to the conclusion that far too much time and money was wasted upon inspectors and inspection of the finished products. Much inspection should be diverted to the personnel, the materials used, the machines, tools and processes. If these are right the finished products will to a great extent look after themselves ; if these are wrong, the products must be wrong.

Assistance can be given in Technical Colleges to give the further knowledge and training to put more skill and interest into the machines and production generally. A few important matters in this respect are as follows : (I am not suggesting that this list covers everything, it is only indicative) Geometry of the action of cutting tools of all types, and of grinding machines for these tools, and of grinding machines of all types : Forces brought into play in cutting action : Good working knowledge of elementary mathematics and all round courses in applied mechanics, machine drawing and electro technics. The design of motions to produce required results. Simple knowledge of strength of materials to enable tools and machines to be designed of sufficient strength and rigidity and of ample wearing surface, and to give the student an appreciation of the stresses coming into play in manufacturing processes. The geometry of wearing surfaces and the geometry of the adjustments for wear. The history and development of tools, machine tools, accessories, and workshop processes and organisation. Why development has been along certain lines. In parenthesis I might mention that old ideas can often be used again with advantage, for example, the re-introduction of dead centre work in modern grinding. The work of Whitworth and others since him in obtaining accuracy. Gauges, their use and manufacture and psychological effect. How to test the accuracy of machine tools. Processes of manufacture. Sequences of operations. Physical Metallurgy of common metals, a much neglected subject in engineering training. Industrial Economics, a very wide subject with many sub-divisions. Psychological effect of good organisation, and one might also add bad as well. Most important of all is the aspect from which, and the frame of mind in which all this is tackled.

When and where is any great attention given to these matters in Technical Colleges ? Only in a small number up and down the country. Staffs are chosen for their academic qualifications and interests rather than for their interests in the everyday matters of the inside of engineering works and allied industries. Many teachers stuffed full of the standard formal knowledge required

for standard examinations cling tenaciously to their stock-in-trade. When a teacher shows an open mind to do his life's work rather than to perpetuate his training and he wants to apply what is possible of his training to production matters, and when his interests and inclinations include production, he has not the time to develop along these lines due to regulations concerning numbers of teaching hours. It is new ground and takes a lot of time to till. Some full-time teachers of the right frame of mind should be told off to give some or all of their time to these important matters and to formulate what might be called the standard knowledge of production. The subject matter in the higher training of productionists must be often varied or revised in accordance with the changes, improvements and progress taking place. The teacher who is teaching 24 hours a week and marking homework, lecture notes, and laboratory work for a hundred students a week has not the time to do it.

The bias from production matters in our work has been made more acute by the introduction of National Certificates of a type having little or nothing to do with production. The National Certificates scheme is good and the present National Certificates are good for their purpose, but another type of National Certificate along production lines is overdue. This would divert interest towards production. It might truly be said that we are attempting to train our students as if they were all of the Whitworth Scholarship type, and neglecting the important production engineer of the Whitworth type. The Whitworth Scholarship type should not be neglected, far from it, but only those whose inclinations are along these lines should be chosen for our present kind of training. Some segregation of these men would enable more progress to be made with them. This does not mean that I look upon the production man as an inferior person, both types of men are complimentary to each other, and each have their spheres of great possibilities and usefulness. Which type of course a student takes should depend greatly upon inclinations, to some extent on mathematical ability, but most important of all is economic domination.

Production gives a big scope for brains and ingenuity and for qualities often lacking in the Whitworth Scholarship or Engineering Physicist type of man, viz., tact and discretion in business matters and in doing what is possible under existing conditions and in the control of men. But production men should realise that these often so called theory men are sometimes correct, they are often idealists who see too far ahead and lack the qualities or force to convey their convictions to others who may not always be able to follow their reasonings through differences in training and experience and interest directed to other channels.

One might moralise here and state that it is but little use being clever by oneself in any field of life. To be effective if one is clever

one must have a following ; others who recognise your cleverness. One of the most potent reasons for the education of the masses is to give to them the means of appreciating men of greater and real ability in order that such men may be made effective. Suppose the economist came forward and showed us a clear road through all our troubles at the present day. Would he be before his time, and should we treat him as Gallileo and other people have been treated ? A man born before his time is not appreciated and hence is ineffective. Educated workmen who appreciate the reasons for doing things will give good organisation, management and improved tools and machines a chance of success by sensible support.

Suggestions in the training of workmen are as follows, and here I should like you to criticise me as much as you can : Every youth as he leaves school should go directly into, or at least under, the control of the Technical College and from the age of 14/15 years to 18/19 years should be given one evening or other teaching period a week actual workshop practice with short lectures on the work in progress and the tools being used. The instruction should be given by the type of mechanics I have mentioned who can in most cases be trained to become good teachers.

The early years is the time to cultivate manipulative ability and interest in the use of tools. My opinion is that a person who cannot use tools by the age of eighteen years never will, and will never have more than a cursory interest in them.

The speaker looks upon the early workshop classes as essential in any production training. After the age of 18/19 years these classes may be dropped and the time given to a workshop lecture and study in a new type of laboratory called the workshop laboratory, particulars of which will be given later.

The remaining two evenings or two other teaching periods a week should be spent on such subjects as English, Mathematics, Mechanics and Geometrical and Mechanical Drawing. [It is the practice in most Technical Colleges to require attendance of students on three and not more than three evenings a week. This leaves students time for homework.]

The greatest difficulty is the provision of workshops equipped with simple machines and tools. These will be expensive but it is submitted that the expenditure would be justified by the results. The type of equipment is rudimentary and not such as would be quickly and seriously out-of-date. Special production machines are not generally required in such workshops. In some cases manufacturers may allow a portion of their works to be used, but there are difficulties.

In Chesterfield we are fortunate in having our Carpentry classes in a new and excellently equipped woodwork shop belonging to a local firm of contractors, the managing director of which is a Councillor with a keen interest in education.

We are equally fortunate in the housing of our practical foundry class ; this is held in a corner of the large and well-equipped foundry of Messrs. Markham and Company Ltd. The foundry manager, a practical man with a keen interest in youths, is the teacher. We have no other shops at present. It must be borne in mind that we are a new college.

Classes in bench work might be conducted in local works but many difficulties are foreseen in attempting to conduct a class in machine tool operations anywhere but in a college workshop.

Suggested work in the workshop laboratory previously mentioned is as follows : (This again is not intended to be a full list, but only indicative) Experiments in hardening and tempering of cutting tools. Experiments in strain hardening and the simple physical properties of metals, hot and cold ; how metals are fashioned to shape ; how can you shape cast iron, you cannot forge cast iron, but the youth does not know, let him have a go at forging a piece. Experiments on red short and cold short metals. Drawing of small wires and the rolling of small sheets of various metals ; let the students roll these in a pair of small rolls and discover the physical properties before and after cold work. Experiments should be made with sets of tools in fly presses with different kinds of metals, an important industry around Birmingham. Visits should be paid to works to see the hot and cold working of metals under commercial conditions. Experiments might be made on the action of wood working tools, width of mouth and action of cap iron in a plane. The study of a shaving from an ordinary plane gives the youths an idea of what happens with tool cutting metals. Experiments on cutting action, speeds and feeds and power required to drive machines. Experiments on cutting action of drills. End thrust and torque of drills of different types with different cutting angles, etc. Testing of files. Testing and adjusting a lathe and other machine tools. Use of measuring instruments and comparators. Calibration of measuring instruments, micrometers, clock indicators, etc. ; when you come to the calibration of micrometers, if you test different makes of micrometers against each other, you will find they have not all got the same inch. Testing of gauges. Planes of reference and testing of jigs. Testing elements of screw threads and screwing tools, finding progressive and periodic errors in threads, finding the causes and correcting for these. Experiments on the cutting action of various types of grinding wheels at various speeds on various metals, wet and dry. Reproduction of trouble experienced with tools and machines. Where you know certain things lead to trouble, let the trouble take place as part of the tuition. Simple experiments on lubrication and the properties of lubricating oils. Tension tests on belts and belt connections, running tests and speed flicker with different belt connections. Generating and testing of plane surface and two plane surfaces parallel with each other. Whitworth generat-

ed plane surfaces. Of late years it has been found possible to generate two plane surfaces parallel to each other, but the skill of man has not yet made possible the generation of a cube, i.e., plane surfaces at right angles to each other. The generation of two plane surfaces parallel to each other has made possible such things as Johannsen gauges. Some of these things may be done by students and they will then appreciate not only the points underlying the generation, but the instability of a piece of steel even to retain constant shape.

One's occupation is a most powerful factor in education, and the first appeal to youths in industry can be made in the early workshop classes by and through the rapidly growing ability and the keen desire to do things with their fingers during the ages up to about 19 years. Those who have not this desire to use their fingers should not be in any production classes.

During and after the ages of 18/19 when the workshop is dropped and the workshop lectures and laboratory introduced for one period a week, the remaining two periods a week for tuition should be given to the remaining subjects or similar ones mentioned earlier in my remarks.

The workshop lectures and laboratory should give subject matter for about three years of study. After this the students may pass to further mathematics classes and study in the technological classes if they so desire, or take special courses of lectures, papers and discussions in production subjects arranged by a Society of post students, or by the college as post production course study.

In the old days, some time before the War, much of the work in the evening Technical Colleges was centred around the Drawing Office ; the work was centred around machine drawing. It seemed to be the height of respectability to start work at nine o'clock in the morning instead of six. Every youth wanted to be a draughtsman.

It has now been recognised that you cannot make draughtsmen in Technical Colleges ; you can give them assistance, but you cannot make them. Neither can you make an Engineer of any type in a Technical College ; you can only give them assistance. A change took place after the War, the centre controlling the teaching was shifted from the Drawing Office to the pivotal subject Engineering Science. What would have been remarkable years ago is now common place, viz., that in some years of a course Machine Drawing and Design is not taken. This change is a distinct improvement in the training of technologists.

Another change is now due ; the centre controlling much of our teaching should again be shifted this time to the shops, the production departments, to the training of productionists as distinct from technologists. The capable productionist is an important man in the economics of engineering and no longer just a superior artisan.

Discussion.

MR. R. H. YOUNGASH, Section President, who presided: The splendid address we have had from Mr. Parsonage is a clear vindication, if one was required, for the existence of this Institution. Those who are eligible for membership are those who have had training such as he has outlined to-night, however it may have been obtained. There can be no question as to the necessity for such training; it simply boils down to the form it ought to take and we must all feel considerable pleasure to find our Educationists are definitely arranging to provide the facilities for future Production Engineers to obtain the knowledge and instruction that older ones have had to get by more roundabout and haphazard methods. A word that Mr. Parsonage has used two or three times, and which I am surprised to hear, is "Productionists." I have not met this before and wonder from where he has obtained it. Mr. Parsonage mentioned the natural ability of certain men to whom, when we were youngsters in the shops, we went with all our troubles. These men were what are commonly termed "born mechanics"; that is, they had a mechanical turn of mind, and it is rather a curious thing that this class of people, as Mr. Parsonage said, very rarely get promoted to be foremen. Many of us have taken one of the best workmen and made him into a foreman only to find that he did not function in the way we expected him to do. The reason for that is, you must have, with your natural mechanical ability, a considerable amount of executive ability, and in this direction many really skilled men are lacking.

One point that has struck me is that Mr. Parsonage has definitely advocated intensive mechanical training rather than purely academical training for production engineers. I was very relieved afterwards when he said that this was not intended to indicate that Production Engineers were less capable or slower in mind than the academic men. There is a definite difference between the training necessary for production engineers and ordinary mechanical engineers, as Mr. Parsonage has made so clear. The question of training the young is always interesting, and we ought to consider not only the boys who are being trained for production engineers, but also the training of operatives. We cannot all be production engineers; some of us have got to be operatives. You will remember that some time ago I very strongly advocated the forming of schools at any rate in the bigger works, where very much of the training Mr. Parsonage has outlined could be given to our operatives, and from those we could select boys more susceptible to tuition who would then receive further training to fit them for the executive posts. Mr. Parsonage himself mentioned the forming of these schools or classes in connection with the works. I think that is an excellent scheme, particularly where it can be comparatively easily arranged in a town like Birmingham, where the scholastic side of it can be

so dealt with. Forging cast iron was one of the illustrations Mr. Parsonage used as an example of valuable training. I think this is an extremely useful suggestion for teaching a boy the limitations of this particular material and further suggest that a very good method of impressing the young with the importance of cutting angles would be to let them do some turning on the homely treadle lathe. In this way he would obtain really first hand knowledge of the effect of varying cutting angles and other important points in connection with lathe tools.

Dr. W. E. Fisher: First of all I would like to express my appreciation of the splendid way in which the speaker has put before you a subject that, so far as I am concerned, comes very near home. He has stated many things which I would like to have said, some which I have said, but not, I think, with quite such incisiveness and force. In that connection I would like to say that I feel like an exceptionally proud father. Mr. Parsonage has been interested in ideas of this particular kind of engineering training for a longer time than I have, but it does happen that many years ago I was in a position to make some first attempts to get these ideas accepted by the authorities for technical education; and after a year or two I was very happy indeed to be able to pass over the mantle to Mr. Parsonage—it hung very skimpily upon his shoulders. The ideas are his own but I am proud to have passed on to him some opportunity of working them out in practice. Now I have said enough to show that I am entirely in sympathy with what Mr. Parsonage has said, and looking round this room I see very little of the opposition. I wonder if I may for a moment try to make a little plainer the view of those educationists of the vested interest against whom, in a sense, Mr. Parsonage has been speaking. He has assumed a particular bias for to-night, but, like myself, he is concerned with both phases of engineering education. The feeling which has been prevalent for a generation is, I think, something like this: "It may be admitted that very few people in an engineering concern have to deal with fundamental design, but the man here and there who is doing so occupies a central and pivotal position. We must make sure that training is available for men who are going to occupy such positions; we don't know exactly who they are, so we had better let the requirements of such positions give the keynote to our scheme of training. If we can only produce a generation of people so trained the few specimens who rise to eminence will have justified us, and the remainder will know enough to act under their leadership. So training in the sciences underlying fundamental design is the first thing we should concentrate upon."

This has actually happened, and it is easy to see that there has been some justification for it. At the moment the point to remember in regard to the Technical Colleges is that the whole task of engineering education is not theirs; there are the Universities as well;

most of our Technical Colleges have scholarship facilities to pass students on to the Universities ; and I feel that there is a far greater risk that we should neglect the aspect of engineering study that has been put before us to-night than that we should by our insistence on production training stifle some possible Charles Parsons. I, at any rate, feel that the risk is greater that way.

I don't know whether any official of your Institution is likely to make mention this evening of the progress that has been made in this newer type of education in many ways, and notably by the invitation to your Institution to co-operate with the City and Guilds of London Institute in setting up certain schemes of study. I would heartily commend to the perusal of any here who are interested in this subject the syllabus published in the most recent issue of the City and Guilds of London Institute's Programme for Machinists', Turners' and Fitters' Works. I trust that I do no wrong in speaking from inside knowledge of the work of your Advisory Committee which dealt with this matter. They were faced with no little problem. The traditional title of the subject was "Machinists', Turners', and Fitters' Work," but from first to last the feeling of the Committee was that they were dealing with something rather larger than the title suggested. Their deliberations have resulted in a scheme of engineering education which is likely to have a very far-reaching effect. I think, however, that the exposition which we have had to-night from the speaker is going to throw a great deal of additional light upon this published scheme. The City and Guilds Institute is first and foremost an educational body ; but it is also an examining body and its prospectuses have to be designed to give a clear statement as to what the scope of the examinations may be. The Committee which framed the scheme were thinking of other things than the mere scope of an examination ; they were thinking of the outlook of the teacher and student ; of methods such as have been spoken of to-night ; they were thinking, I am sure, of a new approach to engineering education. These things cannot entirely be conveyed by means of an examination syllabus, but to-night we have had an expression of the motives which prompted those who discussed that scheme of work. I mention the City and Guilds' scheme particularly because their programme is a national publication and goes into every centre of technical education in the Kingdom ; but, of course, the Graduateship Examination of this Institution is no less an expression of the same ideals in engineering education and on some sides carries the matter much farther.

The speaker referred to the College Workshop. Like him I fail to see that modern engineering education can properly be carried out without some kind of College Workshop. Industry supplies indispensable experience, but there must be some place where ordinary operations can be undertaken with a view to observation rather than production. We are talking of production, yet in these

classes we must get away from it to some extent. In the industrial establishment difficulties have been eliminated one by one until at first it must appear to the beginner that successful production is almost automatic. In the instructional shop these things will crop up again, and the learner himself will have to grapple with them ; he can work in the experimental spirit. The industrial experience of students will vary, but in the College Workshop some jobs will be attempted by all members of the class ; there will be something for the teacher to refer to, some common background, which, I think, is quite indispensable.

There has been much discussion as to whether work of the kind we are discussing to-night is fundamental. It is argued that all students might very well take the usual Course for the Ordinary National Certificate and then specialised work in connection with manufacturing materials and processes for a further certificate. It may be that it is quite possible to take the work in this way, but personally I think work of the type which the speaker has put before us should come first. We are dealing with students of 16, 17, 18 and 19 ; they are in an industrial atmosphere ; are seeing work in progress which is still novel to them, and it is then, I am sure, that we must set them thinking effectively about the principles which control the operations they are seeing or performing. The man of 25 can hardly realise that he is doing things from habit and not from reason. He thinks of the way he works as the only way. At the end of a College education of academic type in which thought has been concentrated upon quite different matters, methods of working will have become habits. I agree with the speaker that we need to set up new Senior Courses rather than to supplement by later work Senior Courses of academic type. Let me once more thank the speaker for dealing so ably with a subject which I feel to be of outstanding interest and importance.

Mr. J. A. Hannay : I would like to call your attention to the time when this Section of the Institution was started in Birmingham, only five years ago, with the help of several prominent engineers. One speaker who addressed us that evening was Mr. Engelbach, and in his remarks about production engineering, he said " What are you going to do about training ? What are the Universities and Technical Colleges going to do ? What courses or definite scholastic arrangements have been made ? " and there was very little to reply at our first meeting. But the Committee made a careful note and passed it on to the Council, and ever since then matters have been progressing. The result, a year or two afterwards, was that Principals, Teachers of the Technological Colleges and some of the Universities, were approached and they have joined the Institution to guide us in our Graduate Examinations. We do feel very grateful that Teachers and Principals in the Technical Colleges have done so much to assist us in this way, and I refer especially to Mr.

Parsonage. Again and again he has come to Birmingham to attend Committee Meetings and give us assistance when we wanted to hear something further on this subject.

When we look back thirty, thirty-five and forty years to the time when some of us started our apprenticeships, altogether five or six years apprenticeship had to be spent in the shop. I think now that with the assistance that can be obtained at Technical Colleges and other sources almost twelve months in the shop would give as much information as the apprenticeship of thirty or forty years ago.

I was speaking recently to a gentleman who is a cost accountant in a large firm in this city, and he told me that just before the War his firm considered they were producing economically a really good article. A few months ago, he said, to keep up with competition and practice to-day, productive capacity had had to be increased thirty times ! It is no use a youth going into a shop to go into one department after another and wade through the works for years and expect to have any chance at all. We have got to have classes where they can learn something of what has been done before. The lack of knowledge of so many young people when they go into the works is terrible. Some of the boys coming in hardly know what a lathe is, and after years of experience they do not get into any other department ; they cannot get to know anything ; their only possible chance is to get knowledge elsewhere than in the shop. They have got to be in the shop to get hard training, but of getting their other information there is no possible hope except in technical colleges.

There was one particular point Mr. Parsonage mentioned, the alignment of machine tools. How many of our apprentices know in their later years how to align a machine ? Yet if only they knew how to do it, how valuable that knowledge would be ! I am very interested when from time to time I get applications from young men asking if they can come to see me and discuss their future ; young men who have served apprenticeships of from two to ten years and they wonder why they are not in some responsible position. I find they lack knowledge which would have been obtained if they had been able to attend classes as outlined by Mr. Parsonage.

I am heartily in agreement with Mr. Parsonage about the age for training. I should not like to keep any young man back from going to the University, but I venture to say that 95 per cent. ought to get into some practical application of the business, and only the other five per cent. enter the University. It is almost tragic that when a man has been to the University and is put into a works or business, he cannot put himself back into the position that the boy of 14, 15 or 16 years is in. He tries to come in at a higher plane and he cannot do it. Only a few people, as I suggested in a paper on another occasion, such as principals' sons, managers' sons and

people whose prospects in life are almost made out for them, should go up to Universities, but I should hesitate to advise any man who has got to make his own way to do so, unless under exceptional circumstances.

Mr. Parsonage's reference to the age at which boys should go into the works, reminded me of a Professor who came over from America two or three years ago. He was sent over by Harvard University, and had been doing a large amount of work for big firms in America, putting labour through various tests, and not only labour but managers and executives. He wanted to get some comparison between executives here and in America. When lecturing before the Rugby Engineering Society, he pointed out that certain tests that were given to boys of 14 and men of, say, 28 years, showed very little difference in the way those tests were handled. Before 14 they did not seem to take interest, but after 14 boys seemed to be able to perform the tests with different degrees of proficiency. He said there was very little difference between14 and 28. It seems that a boy coming from school, at 14, has got the right way of approaching these things just as much as the man of 28. This particularly struck me when Mr. Parsonage emphasized those ages.

For teaching as they have to be taught in the works, I consider that the ages of 14 to 18 are right and that with the training that can be got from the technical colleges, the possibilities for our young men are very bright. I do not say they have thirty times the possibilities that we had thirty or forty years ago, but I should say they have ten times the possibilities, and we have got to have before us the thought " How are we going to bring these young and vigorous men into important posts quickly, instead of allowing them to serve their time and then flounder about before finding their feet ? " We want young men to serve their apprenticeship so that a few years later executives will be able to take them and use them effectively right away.

Mr. E. J. Wiley : I would like to thank Mr. Parsonage for his interesting discourse. People who have to engage youths in industry will be indebted to him, also youths who are taking the production side in education. I happen to know Mr. Parsonage as one of the early men to interest himself in this matter and in the Wednesbury district the result has been noticeable. Previous speakers have mentioned the old time " born mechanic." There is no doubt we were greatly indebted to them as young men. The idea Mr. Parsonage has put before us to-night is that we should enable that same knowledge to be obtained from the colleges, and that is necessary because there are fewer and fewer of the old type of mechanic available for the young men to go to, and unless there is something to take their place, we shall certainly notice their

absence in the effect they have had previously on youths growing up in industry.

MR. MCKNIGHT: I should just like to acknowledge the great debt I owe to Mr. Parsonage. We have tried to carry on the good work Dr. Fisher and he started at Wednesbury. I am very glad to hear that Mr. Parsonage's paper has been accepted by this Institution so eagerly. To some extent he is preaching to the converted, at least so far as I am concerned, and apparently you have been converted too. I hope that the Institution will keep plugging away at the subject so that it will get to the point at which the Education Authorities and Principals have got to move in the matter. I do not see much hope just now, with the Economy Act in operation! It has been suggested before that the production man should specialize later; that he should take the ordinary general course and then go off into his own branch. I should go in the other direction, I think, and have what are called the "major course" studies start with a course in Shop Practice. I have tried to get into operation at Wednesbury a common course for Production and Design Engineering students. There were other matters affecting that proposal and it did not materialise, but we have not lost sight of the question. Some of the students we get have never been in a workshop. I do not know how it is possible to call oneself an engineer after serving time in the Drawing Office only. In connection with that, I think it is a very good thing for students who are going to the University to serve their time first of all and take shop practice from the beginning. I remember when I was at the University, having served my time previously, listening to a lecture on Pistons. The Lecturer dealt exhaustively with every type of Piston. One student went up to him and congratulated him on such an informative lecture, and then said "What puzzled me was, what are pistons for?" When the lecturer recovered from his shock and told him, the student said "Yes, I have very often seen engine cylinders and always wondered what was inside." There is a big amount of time wasted in Universities in descriptive work which men should know before going to the University. That information can be got elsewhere, and I think that one of the best ways of getting it is to serve an apprenticeship first and take evening classes concurrently. A man who is going into design later on must have shop work and shop work has got to come first. After all, it is impossible to do anything worthy of the name of design if the man has got no knowledge of the processes involved in the making of the article; it is one of the fundamentals that design is greatly influenced by the methods to be used in manufacture.

I should like to support the idea of a National Certificate or something of that kind. There is no doubt that the present National Certificate is out-of-date. There is a big percentage of men engaged in production engineering but you will always get a very much small-

er percentage taking that course ; perhaps not always, but at present if you have, say, five per cent. of those engaged in engineering doing design work, you will probably get 30 per cent. select the course of training in design because they think that is more respectable. That point of view will probably alter but only by educating students and education authorities. I think that something on the lines of the National Certificate could be arranged which would be a great attraction to students who want to take a production engineering course. The course we have running at Wednesbury just now is, in the main, due to Mr. Parsonage, and that course allows of students dropping off at various stages. The man who is going to be at the bench or machine all the time, and who is not capable of further progress gets useful training in the early part of the course ; the later parts of our course are for those who have got further possibilities.

Mr. J. W. Berry : One of the most important points in Mr. Parsonage's address was the choice of the Instructor in Technical College Workshops. I have visited several, and I think the Speaker will agree with me when I say that for my part I would rather have a sound, practical man, tempered with theory, instructing in the workshop than a teacher with academical qualifications only.

Mr. J. W. E. Aidney : I would like to see the ideal workshop carried even a bit further. Mr. Hannay, I think, said that very few men, after they have finished their apprenticeship, have any idea of executive work at all. I heard Sir Herbert Austin say, at our Annual Dinner, that the Production Engineer of the future will be not only an engineer and buyer, but quite a lot of other things as well. I should like to see the imaginary buying and installing of machine tools carried out in this way. After the youth has got some idea of what he is going to do in the way of machining, etc., and got that firmly fixed in his mind, start an ideal factory inside the workshop; make up your minds what you are going to produce and sell it for, and get down to the real way of producing the article to sell it at a particular price ; let the youths learn to write letters, buy machine tools, materials, etc., and interview travellers ; draw up specifications. If they have some knowledge of that sort of thing it is going to help them greatly. They do not get that knowledge in these days ; very few firms will allow a man who has been in the works to pass into another department. If youths could get some idea of the processes of making a thing, including price and so on, it would stand them in good stead in the future. I should like to know what Mr. Parsonage thinks about the idea.

Mr. I. H. Wright : Mr. Parsonage spoke about the manual dexterity of certain boys, and the lack of it in others. I think that manual dexterity is something that can be found out when boys are being engaged. I think that all boys are naturally manually dexterous, but our methods of elementary education accentuates

brain work so that manual dexterity is trained out of them. You can train boys not to be manually dexterous, and if manual dexterity is trained out of them, industry has not the time to train it back again. I am going to slate production engineers a bit now. Whatever training and instruction is given, and however well the students do their work, and however good and practical teachers are, unless industry works with them and acknowledges the existence of training, the work is very seriously discounted. I think it is very general—it has been my experience—that management of various firms allow their boys to take time off to attend day courses and do what they can to let them get training, but beyond that they do nothing at all about education. When the boy does something mechanically foolish they curse him a bit and show him the right way to do it. In my opinion they ought to say "Is this the way you learn to do it at school? Now just have a talk with your teacher and see if this is the correct way," and leave the teacher to explain it from fundamentals. In many cases the teacher will not arrive at the same final result as the foreman would have done, but at any rate, it will acknowledge a connection between teaching and the practical work in the shop. It would be a very great help.

As far as the question of a further National Certificate, which has been referred to once or twice, is conerned, we do not want a "blanket" certificate. I think there is every justification for holding to the practical production side of engineering that is distinct from the present side which is almost generally on the lines of designing engineering, and I do not see how one certificate can be adapted, for both types of training and qualifications.

Mr. W. G. Groocock: I have been intensely interested in what Mr. Parsonage has been telling us, and from the point of view of discussion, feel somewhat at a disadvantage, as I find myself very much in sympathy with everything that he has said. I would like to see the syllabus that Mr. Parsonage has put forward, adopted, because I believe it would be very useful. I say this, not because I am dissatisfied with the syllabus at present in use, but rather from the fact that the present syllabus is somewhat disconnected. In my opinion it is not the syllabus in use at the present time that is faulty, but rather that the teachers themselves do not follow the technical training through to its logical conclusion. In teaching our young men along technical lines, we want always to impress on them that their education is a tool for their use and, like a micrometer in the hands of a tool maker, unless they can use the tools placed at their disposal, then such tools are of no use. The great drawback to many technical students that one meets is that when they go into the workshop they have not the slightest idea of applying what they have learnt to the work they have in hand. It can be said with certainty that it is no good learning a formula or how to do things, unless one has the good sense of being able

to apply it. A head full of formula is useless if the bases of the formula are unknown and they cannot be applied.

The best examples of this kind of thing are, I think the students from India. They have wonderful memories and what they learn at the technical schools and colleges they can carry in their head in such a way that they can easily pass examinations, but unfortunately for them they can rarely use such information in the shops. Quite apart from any system of education that may be in use, there is one thing that we as an Institution of Production Engineers definitely want from the educational authorities. We want built up in the minds of the students what I would call a production mentality; the mentality that is determined to make two blades of grass grow where only one grew before, and then, having achieved this, still be determined to again double the output. That is the type of mentality that has brought us in the production world to our present position. It is the mentality that will carry us further in the future. There are, I know, difficulties at the present time in trying to instil this type of mentality and to make it square with our present economic position. It is particularly difficult at the present time because most people think—and naturally so—that if we are producing two pieces where we have only previously produced one, then this of necessity means that some man has to go out of work. Whether this is a fact or not does not concern us as production engineers. Our job is to produce as much as we possibly can, and when we have doubled our output we must start and double it again. It is only by such means that we can achieve a higher standard of life. I like the idea put forward by Mr. Parsonage, namely, to find the old-time all round mechanic and to instal him in a technical school with a view to passing on his manipulative skill to our young men. The idea is fine, but unless we have behind it the productive mentality that I have mentioned, we may possibly fail from the production point of view. Many of the finest mechanics we know are lacking in this correct mental attitude. They could make almost anything from a scrap heap, but they have not a proper appreciation of time and value.

I feel inclined to agree with what Mr. Aidney has said that we ought to carry our courses a little further than has been suggested by Mr. Parsonage, and I suggest that the ultimate aim of all such courses should be—first, to implant the necessary desire for manipulative skill; secondly, a full knowledge of the fact that education must be applied before it is valuable; and lastly that the present age is a purely competitive one, and the whole aim of manipulative skill and education is to produce goods quickly and cheaply. I agree with Mr. Parsonage when he said that he would like to make the workshop the foundation. My view is that a boy stands the best chance if he starts in the workshop and later on, if he has the opportunity and the necessary ability, carries on with technical training.

Mr. Groocock then proposed a vote of thanks to the lecturer.

MR. PARSONAGE (replying): I thank you for the very kind way in which you have received and discussed my Paper. The Chairman mentions the word "Productionist." I do not know that I have seen the word anywhere, so must plead guilty to having coined it. Well-known cases of using "-ist" are, technologist, metallurgist, physicisist, biologist, economist, and we have the peculiar word stockist used in commerce. So why not "Productionist"? It is a shorter word and more quickly said than production engineer, but do not think that the word "Productionist" is intended to imply that the production man is not an engineer.

Regarding your remarks, Mr. Chairman, about good workmen not always making good foremen, there is something but not everything in getting your man young for training as a foreman, just as you catch him young for training as a teacher. During my apprenticeship I met many excellent workmen. A few years later I was instrumental in getting one to give assistance in the workshop classes at the Central Technical College, Birmingham. He was the most capable man on the lathe that it has ever been my pleasure and to my advantage to meet, and the most excellent teacher of machine tool practice. All old Bellis men will know him and will agree with me. He died a few months ago; his name was John Maas, a brother of the great tenor singer of the late 'Eighties. He is typical of the kind of man I have in mind in my Paper to become a teacher. Other good men who have been older and become foremen, I have seen in teaching posts but foremanship and age had crystallised them out into taskmasters only and they were hopeless as teachers. You must get your man at about 24 years of age, certainly before he is 30. I quite realise, however, that a foreman must have executive ability and without this you cannot have a good foreman at whatever age you catch him.

I am pleased for many reasons to hear, Mr. Chairman, that you have advocated the forming of schools in the bigger works. It would, in my opinion, be a move in the right direction. I agree, from painful personal experience, with your suggestion about some work on a treadle lathe, but not too much work.

I am grateful to Dr. Fisher for his complimentary and complementary remarks. He has mentioned many salient features omitted by me. He has put the underlying reasons for our present type of technological course very tersely and effectively. He agrees with my suggestions and very wisely points out a real danger but not one that would exist where Dr. Fisher was in control. No budding Charles Parsons would slip unrecognised through his fingers. When Dr. Fisher mentions that the whole task of engineering education is not the Technical Colleges, he again indicates a danger and gets very near indeed definitely to mentioning it, namely, that Technical Colleges may not have a sufficient number of scholarships

(some have none) to enable them to pass on to the Universities the brain power in the Technical Colleges benefitable by University training. He mentions the great risk of neglecting the aspect of engineering mentioned in my paper. Young men educable along production lines are likely to be killed off by technological courses, and latent ability thereby not being developed is lost to industry. It should be clearly stated and understood that this means no slight to the production man ; it is distinctly otherwise ; it is a long last proper recognition of him and his importance in industry. Also it should be understood that a man may be both a first-class technologist and a first-class production man, and vice versa.

Dr. Fisher is with me in my opinion about the years in which workshop training should be given. The youths' increasing ability with their fingers is a powerful method of approach to education during the early years. If not used then you have lost your tide. It was in 1920 that I had the advantage of following Dr. Fisher in his post at the County Technical College, Wednesbury, and found with pleasure that he had formulated a system of training for production which I carried on. Dr. Fisher's course made me proud of my " Father." Now I have left the post the work is being further developed by Mr. McKnight.

My introduction to classes other than technological ones was in 1903, but under conditions rendering any developments impossible. The next development was in the early Spring of 1915, when, working under my then Chief, the late Mr. Thomas Reid, at the Central Technical College, Birmingham, I drew up the syllabus and became an Instructor to the first class in the country, as far as I am aware, for the training of munition workers ; the students were Belgian refugees. It was the experience with this class and following ones which showed the great possibilities of production training. The class was visited by many and classes were started by others in many places. The present production courses now being conducted at Wolverhampton, Wednesbury, Birmingham and Loughborough are of course further and also independent developments along production lines. There is now a mass of experience strengthening the standpoint underlying my Paper.

I agree entirely with Mr. Hannay that much of the time, five, six or perhaps seven years, that was spent in apprenticeship under the old conditions was wasted. I am convinced that youths taught in the type of workshop and under the conditions I have outlined could be brought to any degree of skill in a small fraction of the time spent in the old apprenticeship system.

It is a pleasure to see Mr. McKnight here, and I thank him for his helpful remarks and would like to say how I appreciate the good work he is doing. I wish him every success in his attempt to introduce and develop common courses on production lines for the early years of both production and technological students. He and Mr. Groocock raise a very old controversial point about the shop training

of a mechanical engineer : should it precede or follow a college training ? Personally, I agree with them ; shop first with the evenings, and some afternoons if possible, spent in a Technical College.

In reply to Mr. Wright's remarks about manual dexterity being trained out of boys, I agree with him that this was so in the past, but his statement is a little all too embracing for the present. I might mention that the well-known great schoolmaster, Sanderson of Oundle, one of our biggest and most important Public Schools, was in the 'Nineties much impressed by the educational advantages of the workshops and the hand and eye training which was then being developed in the Elementary Schools. Against the wishes of parents, he introduced at Oundle a woodwork shop, and a metalwork shop, including a smithy, at a time when interest in such things and ability in the use of tools was considered to be a sign of plebeian birth and instincts. Sanderson was a strong man and an original thinker. He saw the advantage of this approach to education. The shops were a thorough success. They are still there, further developed, and the example has been copied by other Public Schools. Similar training is now given in Elementary Schools and Secondary Schools in all large towns. It was introduced in London and Birmingham as far back as the early 'Nineties and one of the objects of doing so was then stated to be an effort to counteract the tendency and the desire of so many boys to seek black-coated jobs. The work has not developed exactly along the lines I should have preferred, and I think the same idea is at the back of Mr. Berry's mind. The work has been rather too much schoolmastered, being made too much into an ordinary school subject.

We in education wish that industry would always make the close contact with us desired by Mr. Wright ; who correctly points out our limitations when he says, " Beyond this the schools cannot really go very far." He there partly answers Mr. Aidney for me. Some of the things mentioned by Mr. Aidney are done in a few Technical Colleges and should be done in more. Engineering students take classes in commerce, economics and commercial, law, etc., but one's job can only be learned at the job, and all we can do in a college is to give the student that training which we hope will enable him to act intelligently in the unrehearsed emergencies and exigencies of life, whether they be in simply doing his little job or in interviewing travellers, customers, the managing director or a bank manager. I appreciate Mr. Groocock's remarks and agree with him in the necessity for a production mentality. It is important that the courses outlined by me should be approached, as I have suggested in the Paper, in the proper frame of mind. The persons in control must have a production mentality. If the production mentality and production lead to economic troubles, that is not the fault of the production engineer, and it is not his function to find the remedy. It is the function of the philosopher and the economist and they should point out the remedy.